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A STUDY OF DUST SUPPRESSANTS IN ONTARIO

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FINAL REPORT

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A STUDY OF DUST SUPPRESSANTS IN ONTARIO

Final Report

Report prepared for:

The Ontario Ministry of the Environment and Energy
Waste Management Branch

by

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EXECUTIVE SUMMARY

Large quantities of materials are applied to unpaved roads and other surfaces in Ontario with the chief objective of dust suppression. The primary purposes of applying dust suppressants to roadway surfaces are:

- To reduce the emissions of airborne dust and related hazards to humans.
- To reduce the erosion of surface materials due to loss of fines and coarse aggregate.
- To provide a safer surface for the travelling vehicle.

Several factors affect the effectiveness of dust suppressants, including:

- Surface material.
- Climate (wind, temperature, humidity and precipitation).
- Vehicular or animal traffic (density and type).

Until 1989, waste oil was the most popular dust suppressant used in Ontario on roads and surfaces, because it was perceived by users to be the least expensive and most effective dust suppressant. A ban on the use of waste oil as a dust suppressant was legislated under Ontario Regulation 309 in 1989.

The environmental impacts of waste oil were studied in detail to provide information to support the ban on its use as a dust suppressant. At the time of the ban, several other dust suppressants were also used in various parts of Ontario. These, referred to as "traditional" dust suppressants, have been used to a much greater extent in recent years, to replace the use of waste oil. The environmental impacts of traditional dust suppressants, as well as their technical effectiveness, have not been documented in any comprehensive and standardized format. In addition, there is a concern with the use of oil based products given the choice of and the technical effectiveness of other dust suppressants.

The principal objectives of this study were:

1. To identify locations in Ontario where virgin oil or petroleum products are the only technically and cost effective dust suppressants.

2. To carry out a field test of effectiveness of virgin oil as a dust suppressant to show that it is effective under specific conditions, where other traditional dust suppressants are not effective.

3. To develop a list of Review Parameters that can be used by the Ministries of the Environment and Transportation to evaluate the technical effectiveness and environmental acceptability of dust suppressants.

4. To provide the Review Parameter information for each of the traditional dust suppressants.

5. To develop a Product Application Sheet that instructs dust suppressant applicators on the safe handling, storage, and application of dust suppressants that will ensure technical effectiveness and environmental acceptability.

6. To complete a Product Application Sheet for each of the traditional dust suppressants included in the study.

7. To prepare a report that presents the study methodologies, results and findings, and information sources to the Ministry of the Environment Project Committee.

Main findings in this study of dust suppressants used in Ontario are summarized below:

General

1. Ten traditional dust suppressants were available for use in Ontario at the time of the ban on waste oils, including calcium chloride brine, oil field brine, two pulping liquors (Tembind and Road Binder), two petroleum based emulsions (DCS225 and Dust Bond), three virgin oils (line wash oil, coke wash oil and bunker fuel oil) and rerefined oil.

2. Calcium chloride is the most widely used dust suppressant in Ontario. Bunker fuel oil and rerefined oil are not currently used as dust suppressants.

Effectiveness and Cost

1. Brines in general are most effective on roads with a good mix of fine and porous materials and in humid conditions. Pulping liquors perform optimally where road materials have a high percentage of fines, and in very dry weather. Oils and petroleum based products perform well when the road materials have both fines and sand, but also where the road materials are porous (i.e. no fines). Oils are reported to be more effective than petroleum based products in controlling dust.

2. Road Binder is the least expensive road dust suppressant at \$0.01 to \$0.02/m^2 per season. Road treatment with brines, Tembind and oils typically range in cost from \$0.10 to \$0.50/m^2 per season. Petroleum emulsion products are most

expensive. Costs vary depending on frequency of application required, based on traffic load, surface materials and climate.

Chemical Composition and Effects

1. Brines contain persistent salts, including sodium and chloride, which migrate readily from the application site with water. Chloride has the potential to affect growth and germination of vegetation, and both sodium and chloride can build-up in surface waters. Significant impacts resulting from dust suppressant applications have not been reported.

2. All dust suppressants except brines consist of a large biodegradable component, which has the potential to reduce dissolved oxygen concentrations in surface waters. However, these impacts should not be a concern if care is taken not to apply dust suppressants in the vicinity of surface water.

3. Various metals were detected in all materials, at a range of levels, with the highest levels in bunker fuel. Studies indicate that metals in all traditional dust suppressants, were not at levels that would contribute to human or environmental toxic effects or have impacts on the environment under recommended application. Long-term build-up of metals after frequent application has not been established.

4. Volatile organic compounds (VOC) present in all petroleum based products will not persist at the application site, as they will evaporate. However, these compounds have some adverse toxic and sub-lethal effects. Exposure may occur through inhalation of mist during application, or fumes for a short time after application.

5. Polynuclear aromatic hydrocarbon (PAH) compounds present in all of these petroleum based products, except line wash oil, may have carcinogenic, teratogenic and/or mutagenic properties. Heavier compounds which are those of most concern, will persist at the application site. Routes of exposure may include inhalation of mist during application or inhalation of road dust.

6. Phenolics compounds are present in Road Binder. Because these compounds have been shown to migrate little from the application site and degrade rapidly, environmental impacts and toxic effects are not likely to result if application in the vicinity of surface waters is avoided.

Acute Toxicity

1. Oil field brine is the least toxic non-petroleum based dust suppressant to rainbow trout and Daphnia magna, followed by calcium chloride and the two pulping liquors. The petroleum based emulsions were the most toxic. The toxicity of oils was measured only on those product components which dissolved in water and direct comparison to results for the remaining products is not possible. Of the oils tested, coke wash oil was the most toxic. Lethal dosages of bunker fuel and rerefined oil exceeded 10,000 mg/L.

Examination of Petroleum Based Dust Suppressants

1. In Ontario, there are specific circumstances where oils are believed by users to be the only cost effective dust suppressant. These are where road materials have little or no fines content and dry conditions, where there is heavy and/or high volume traffic, and other unusual circumstances (i.e. horse arenas).

2. In a road test carried out for this study, oil controlled dust to a greater extent than calcium chloride on a surface with porous materials (i.e. no fines) immediately after application. The calcium chloride treated section emitted less dust 4 weeks later, in a 2 day period after a heavy rainfall, although the oil section also performed adequately.

3. Only two alternative products to those covered in the group of traditional dust suppressants were identified that could potentially control dust on surfaces currently using oil. Environmental impacts and effectiveness of these products have not been defined.

4. Environmental impacts of using virgin oil for road dust suppression could be controlled by:

    - Setting limits on contaminants in oils to be applied to roads.
    - Identifying alternatives to oil that would be as cost and technically effective.
    - Paving roads, where available dust suppressants will not perform effectively.

Chapter 1
INTRODUCTION

1.1 BACKGROUND

Large quantities of materials are applied to unpaved roads and other surfaces in Ontario with the primary objective of dust suppression. Dust suppressants are applied to private and public roadways, parking lots and yards (i.e. loading yards) by both municipalities and private industries. In addition, industries use dust suppressants to control wind erosion of raw material or waste piles (e.g. coal, mine tailings, etc.).

The primary purposes of applying dust suppressants to roadway surfaces are:

- To reduce the emissions of airborne dust and related hazards to humans.
- To reduce the erosion of surface materials due to loss of fines and coarse aggregate.
- To provide a safer surface for the travelling vehicle.

Several factors affect the effectiveness of dust suppressants, including:

- Surface material.
- Climate (wind, temperature, humidity and precipitation).
- Vehicular or animal traffic (density and type).

Until 1989, waste oil was the most popular dust suppressant used in Ontario on roads and surfaces, because it was perceived by users to be the least expensive and most effective dust suppressant. Recent concerns over the long-term environmental effects of waste oils as dust suppressants, have resulted in the Ontario Ministry of the Environment banning the use of waste oil as a dust suppressant. This ban was legislated under Ontario Regulation 309 in 1989.

The environmental impacts of waste oil were studied in detail to provide information to support the ban on its use as a dust suppressant. At the time of the ban, several other dust suppressants including virgin oils and petroleum based products, brines and lignosulphonates were also used in various parts of Ontario. These, referred to as "traditional" dust suppressants, have been used to a much greater extent in recent years, to replace the use of waste oil. The environmental impacts of traditional dust suppressants, as well as their technical effectiveness, have not been documented in any

comprehensive and standardized format. In addition, there is a concern with the use of oil based products given the choice of and the technical effectiveness of other dust suppressants.

1.2 STUDY OBJECTIVES

CH2M HILL ENGINEERING LTD. carried out this study in response to the Ontario Ministry of the Environment's request to provide information on traditional dust suppressants used in Ontario. The main purposes of the study were:

- To identify locations in Ontario where petroleum products are the only technically and cost effective method for dust suppression.
- To define a set of review parameters that can be used to evaluate the environmental impacts and technical effectiveness of dust suppressants.
- To provide review parameter information for the traditional dust suppressants used in Ontario.

The principal objectives of this study were:

1. To identify locations in Ontario where virgin oil or petroleum products are the only technically and cost effective dust suppressants.
2. To carry out a field test of effectiveness of virgin oil as a dust suppressant to show that it is effective under specific conditions, where other traditional dust suppressants are not effective.
3. To develop a list of Review Parameters that can be used by the Ministries of the Environment and Transportation to evaluate the technical effectiveness and environmental acceptability of dust suppressants.
4. To provide the Review Parameter information for each of the traditional dust suppressants.
5. To develop a Product Application Sheet that instructs dust suppressant applications on the safe handling, storage, and application of dust suppressants that will ensure technical effectiveness and environmental acceptability.
6. To complete a Product Application Sheet for each of the traditional dust suppressants included in the study.
7. To prepare a report that presents the study methodologies, results and findings, and information sources to the Ministry of the Environment Project Committee.

Chapter 2
STUDY DEFINITION

According to the Terms of Reference, the study consisted of several activities that were interrelated to provide information on traditional dust suppressants used in Ontario. This section presents a clarification of the study requirements, broken down under the following headings:

- Information requirements for traditional dust suppressants.
- Assessment of petroleum based dust suppressants.

2.1 INFORMATION REQUIREMENTS FOR TRADITIONAL DUST SUPPRESSANTS

2.1.1 Traditional Dust Suppressants

In 1989, when the Ontario Ministry of the Environment issued a ban on the use of waste oil as a dust suppressant, a range of alternative dust suppressants were available in Ontario. Referred to as traditional dust suppressants, these included the following types of materials:

- Calcium chloride brines.
- Wood pulping liquors.
- Petroleum based products.
- Virgin oils.

Table 2.1 presents the list of traditional dust suppressants defined for this study. The list includes two calcium chloride based brine agents: manufactured calcium chloride in solution or flake form, as well as oil field brine. In addition, there are two wood pulping liquors; Tembind is an ammonium lignosulphonate product; Road Binder is a pulping liquor produced in the sodium carbonate pulping process. Two petroleum based products marketed solely as dust suppressants were also included, one a petroleum emulsion and the other, an asphalt emulsion. Four oil products, including three virgin oils and rerefined oil, were identified as being those available for use as a road dust suppressant, although not all of these products are currently used in this application.

Review parameter information and Product Application sheets were compiled for each of the traditional dust suppressants presented in Table 2.1.

Two dust suppressants, salt brine (drilled solely for the purpose of dust suppression) and Lignosol AP, were removed from the original list of traditional dust suppressants, since neither of these materials are currently available in Ontario.

Table 2.1
Traditional Dust Suppressants

Name	Description	Manufacturer/Supplier/Distributor
Brines		
Calcium chloride	Manufactured 35% solution or 77% flake.	General Chemical Canada Ltd.
Oil field brine	Formation water generated from oil exploration operations in south western Ontario.	Generated at several locations in Ontario, and distributed by McKeggan Trucking Ltd. and Denis Marcus Ltd.
Pulping Liquors		
Road Binder	Sodium carbonate based spent pulping liquor.	Domtar Packaging Container Board Division
Tembind	Ammonium lignosulphonate.	Temfibre Inc.
Petroleum Based Products		
Dust Bond	Petroleum resin emulsion.	Manufactured by Dust Allayers Inc. in the U.S. and distributed in Ontario by Da-Lee Dust Control.
DCS-225	Asphalt and tall oil emulsion.	NorJohn Ltd.
Virgin and Rerefined Oils		
Coke wash oil	Hydrotreated oil without additives produced for the primary purpose for spraying coke piles for dust suppression.	Several Ontario petroleum refineries.
Line wash oil	High grade base stock virgin oils that have been used to flush process lines between production runs.	Several Ontario petroleum refineries.
Bunker fuel oil	Residual fuel normally burned as fuel oil for heating.	Several Ontario petroleum refineries.
Rerefined oil	Rerefined lubricating oil.	Safety Kleen Breslube Division

2.1.2 Review Parameters

Table 2.2 presents the list of review parameters for the characterization of traditional dust suppressants considered in this study. In future, this list will be used as a list of requirements for evaluating dust suppressants proposed for use in the Province. The parameters are divided into the following categories:

- General information, including description, manufacturer and supplier, costs, source and handling requirements.

Table 2.2
Review Parameter Lists for Dust Suppressants

A. General Information

Description

Manufacturer/Suppliers/Applicators

Cost information
- Product cost
- Transportation cost
- Application cost
- Total cost

Handling procedures
- Personal protection
- Storage
- Transportation and shipping
- Spill procedures

Source description and quality control

B. Technical Effectiveness and Application Procedures

Technical effectiveness
- Review of literature and survey information on factors affecting effectiveness.
- Summary of main points.

Application procedures
- Surface preparation
- Site restrictions
- Application equipment
- Personnel requirements
- Length of time before and after precipitation
- Dilution and mixing hazards
- Application rates and frequency
- Curing time
- Problems and hazards

C. Physical and Chemical Characteristics

Physical characteristics, including:
- Appearance and physical state
- Density
- Odour
- Other parameters, where applicable.

cont'd

C. Physical and Chemical Characteristics (cont'd)

Chemical characteristics
- Break down of main components in % by weight (e.g. solution, solids, oil and grease, water, lignin, etc.)
- Concentration of chemical contaminants:
  - Conventional parameters (total solids, BOD_5, ammonia, total phosphorus, pH, oil & grease)
  - Metals (Al, Ba, B, Cd, Cu, Fe, Pb, Mn, Ni, Sr, Zn, As, Hg, Se and Ca, Mg, Na)
  - Other contaminants specific to the dust suppressant.

Background levels, environmental quality objectives, guidelines and standards

D. Toxicity and Sub-Lethal Effects

Acute toxicity
- Daphnia magna LC50 (48 hour) concentration.
- Rainbow trout LC50 (96 hour) concentration.
- Other acute toxicity information.

Sub-lethal effects
- Literature review of toxic and sub-lethal effects of dust suppressant and significant contaminants in dust suppressant

Summary of acute toxicity and sub-lethal effects

E. Environmental Impacts

Literature review of environmental impacts (i.e. persistence and migration) of:
- Main dust suppressant components
- Contaminants

Summary of environmental impacts

F. Other Impacts Related to Dust Suppressant Use

- Technical effectiveness and application procedures.
- Physical and chemical characteristics.
- Toxicity and sub-lethal effects.
- Environmental impacts.
- Other impacts.

The methodologies for collecting review parameter information on each of the traditional dust suppressants included literature searches, telephone surveys, laboratory testing and some road testing. Details on these activities are presented in Chapter 3 of this report.

2.1.3 Product Application Sheet

A Product Application Sheet designed for this study is intended to provide instructions to the applicator of a dust suppressant on the handling and application of the material to ensure safety, effective performance and environmental acceptability. It is intended by the Ontario Ministry of the Environment that all shipments of a dust suppressant will be accompanied by a Product Application Sheet. Table 2.3 presents the information on a Product Application Sheet. A Product Application Sheet was prepared for each traditional dust suppressant as part of this study.

Table 2.3
Dust Suppressant Product Application Sheet

A. General Information • General description • Manufacturer/distributor information **B. Handling Procedures** • Personal protection • Emergency first aid • Transportation requirements • Spill Procedure and emergency phone numbers	**C. Application Procedures** • Pre-application considerations - surface preparation - where to apply and site restrictions - when to apply • Application - personnel - equipment - dilution and mixing hazards - rates - frequency - curing time - problems and hazards

2.2 ASSESSMENT OF PETROLEUM BASED DUST SUPPRESSANTS

One of the primary objectives of the study was to identify where in Ontario petroleum products are considered to be the only cost and technically effective dust suppressant. Technical effectiveness is defined by how well the product performs in controlling dust and stabilizing surfaces under the specific road conditions (surface materials, climate, traffic) it is applied. Cost effectiveness is represented not only by the cost of the product for a single application, but also by the length of effective lifetime and the frequency of application required.

A comparative assessment of the costs, application rates and frequencies, and effectiveness of traditional dust suppressants under a range of conditions was carried out to identify where petroleum based products are the only acceptable dust suppressants.

There are also a number of "non-traditional" dust suppressants currently under review in Ontario. Cost and performance information, as available from the supplier/distributor, were also compiled to provide additional information on potential alternatives to petroleum based dust suppressants.

Chapter 3
STUDY COMPONENTS

Several activities were undertaken as part of the study to provide review parameter information, and to carry out a comparative assessment of costs and effectiveness of dust suppressants. These activities included:

- A telephone survey of Ontario dust suppressant users, applicators, suppliers and manufacturers.
- A literature review and telephone survey of information on non-traditional dust suppressants.
- A literature search for information on the technical effectiveness and environmental impacts of traditional dust suppressants.
- Chemical analyses of traditional dust suppressants.
- Aquatic toxicity testing of traditional dust suppressants.
- A review of background levels, guidelines and objectives for the contaminants detected in traditional dust suppressants.
- A literature search for information on the toxic and sub-lethal effects of traditional dust suppressants and significant contaminants.

The objectives of each of the above activities, study methodologies, and results are presented in the following subsections.

In addition, a detailed evaluation of the use of petroleum based dust suppressants in Ontario was also carried out to meet the study objectives. Specific components of this evaluation, which included a field testing program, are presented in Chapter 6.

3.1 SURVEY OF ONTARIO USERS, APPLICATORS, SUPPLIERS AND MANUFACTURERS

Purpose

A telephone survey of organizations involved in the life cycle of traditional dust suppressants was conducted. These organizations included the manufacturers, suppliers and distributors, applicators and users. The objectives of the survey were to obtain an overview of the costs, handling, use and performance of traditional dust suppressants in Ontario, with particular focus on the relative performance of petroleum based products.

Methodologies

The telephone survey was carried out in three phases, starting with the manufacturers and suppliers, then applicators and users. Table 3.1 presents a list of all organizations involved in the survey. These organizations were identified from a number of sources, including the Ministry of the Environment, and the manufacturers, suppliers and applicators of the materials. All phone contacts were made by a CH2M HILL engineer according to a prepared prompt sheet, to ensure consistency and completeness. All answers were recorded on the prompt sheet.

With the exception of Dust Bond and Tembind, all of the dust suppressants are produced or generated in Ontario. At the outset of the study, it was unclear which petroleum refineries in Ontario produce which virgin oil products for dust suppression. Therefore, a survey of three oil companies was carried out.

The information requested from the suppliers and distributors included:

- Dust suppressant costs.
- Manufacturing process description, source, and quality control.
- The Materials Safety Data Sheet (MSDS) for the dust suppressant.
- Any studies or information available on chemical composition, toxicity, environmental impacts and technical performance.
- The manufacturers suggested use, in terms of application rates and frequency.
- The surface, traffic density and climate conditions for which the dust suppressant is designed.
- Identification of applicators in Ontario who purchase their dust suppressant.
- Identification of users of their dust suppressant in Ontario.
- For the virgin oils, which oil products have been used or could potentially be used for road dust suppression.

Based on information provided by the suppliers, major applicators of each dust suppressant were surveyed. The Ontario suppliers of several dust suppressants, including Dust Bond, DCS-225, Tembind, Road Binder, and oil field brine also provide application services, although private contractors may also apply these materials. Only two applicators were identified for the application of virgin oil products. However, smaller applicators in the Province may also provide this service. Applicators of re-

Table 3.1
Organizations Surveyed in Study

Dust Suppressant	Manufacturers and Suppliers	Applicators	Users
Calcium chloride	General Chemical Canada Ltd., Amhurstburg	• Miller Paving Co. Ltd., Markham • Polland Bros. Co., Harrow • Chambers Road Oil, Gravenhurst • Keith Thompson Ltd., Sudbury	• Algonquin Park • Town of Huntsville • Ontario Ministry of Transportation - northern Ontario logging roads - Thunder Bay area roads • Sandbanks Provincial Park, Trenton • Township of Burford • South West Sales Corporation (gravel depot), Windsor • Township of Brighton • St. Lawrence Seaway Park, St. Catherine • Town of Gravenhurst • Township of Barrie • Township of Orillia • City of Orillia • Town of Ancaster • Town of Dundas • Township of Glanbrook • Town of Flamborough • Regional Municipality of Hamilton Wentworth • Town of Dunville
Oil field brine	From several drilling operations in Southwestern Ontario (Contact the Ontario Petroleum Institute)	• McKeegan Trucking Ltd., Sombra • Harold Marcus Ltd., Bothwell	• South West Sales Corp., Windsor • St. Clair Parkway (Parks and Marina), Corunna
Tembind	Temfibre Inc., Temiscaming, P.Q.	• Temfibre Inc., Temiscaming, P.Q.	• City of Sault Ste. Marie • Town of Huntsville • Town of Milton • Port Carling (Township of Muskoka)
Road Binder	Domtar Packaging Containerboard Division, Trenton	• Domtar Packaging Containerboard Division, Trenton	• Township of Camden • Township of Hallowell • Township of Brighton • Township of Murray • Township of Haldimand
Dust Bond	DAI Emulsions, Mansfield, Ohio	• Da-Lee Dust Control, Fruitland	• Saugeen Indian Reserve • Bartram Lumber Yard, Stoney Creek • Bayshore Vegetable Shippers Ltd., Burlington • Town of Huntsville
DCS-225	NorJohn Ltd., Thorold	• NorJohn Ltd., Thorold	• Port Carling (Township of Muskoka) • Township of Lake of Bays • City of St. Thomas

Table 3.1
Organizations Surveyed in Study

Dust Suppressant	Manufacturers and Suppliers	Applicators	Users
Virgin Oils	Petro Canada Products Esso Petroleum Canada Shell Canada Products Ltd.	• NorJohn Ltd., Thorold • Da-Lee Dust Control, Fruitland	• Bernstein Brick Yard, St. Catharines • Bayshore Vegetable Shippers Ltd., Burlington • Batram Lumber Yard, St. Catharines • Town of Huntsville • Stelco Inc., Hamilton • Bertin Stables, Toronto • Town of Milton • Sherman Sand and Gravel, Milton • Township of Norfolk • Town of Haldimand
Rerefined Oil	Safety-Kleen Canada Inc., Breslau	No applicators identified.	No current or past users identified.

refined oil were not identified, and the manufacturer, Safety Kleen, reports that this product has never been used for road dust suppression purposes. Calcium chloride is the most widely used material in Ontario, and several applicators exist, of which four representatives were surveyed.

The information requested from the applicators included:

- Application costs.
- Application methods, including road preparation, equipment, personnel, procedures, dilution, rates and frequency.
- Transportation requirements.
- Reports, based on their experiences, on the conditions that affect dust suppressant effectiveness or effective life. Applicators were asked specifically about performance in sand and clay surfaces; wet, humid and dry climates; heavy and light traffic loads.
- Identification of Ontario users of the dust suppressant(s) they apply.

From the lists of dust suppressant users provided by the suppliers and applicators, representative users were selected for the survey. The surveyed group covered:

- The full range of traditional dust suppressants.
- A geographical spread across the Province.

- A range of conditions, including wet and dry weather, various surface materials and traffic weights and densities.

- A range of surface uses, including municipal roads, industrial yards, industrial roads, horse arenas, etc.

- Users who had experience with more than one dust suppressant.

Information requested from users during the telephone survey included:

- Their total seasonal cost, including dust suppressant and application, and considering application rates and frequency.

- Reports based on their experience, of the conditions that affect dust suppressant effectiveness or effective life. Users were asked specifically about performance in sand and clay surfaces; wet, humid and dry climates; heavy and light traffic loads.

- If they have used another dust suppressant in the past, particularly waste or virgin oil, and their comments on relative performance and costs.

- If they use virgin oils, why they have chosen this product and the reasons other dust suppressants are not used at this site.

- Comments on any environmental or other effects experienced as a result of dust suppressant use.

All of the survey information contained on the questionnaires was used in the preparation of review parameters for traditional dust suppressants and the comparative analysis of dust suppressants.

Survey Findings

In general, information provided by manufacturers and suppliers of traditional dust suppressants was limited to the data on costs, and the material itself. This included MSDS sheets, which outline main product components, physical properties, safety and handling procedures, and first aid. With the exception of Domtar (Road Binder), factors that affect performance, chemical characteristics and environmental impacts have not been studied by the supplier or manufacturer. Most suppliers have established recommended application rates and frequencies to achieve maximum performance.

Dust suppressant applicators provided information on their costs, and additional information on handling and transportation requirements. Many applicators have formal or informal guidelines for application rates, which were provided. Applicators have

generally documented equipment requirements and information on these was supplemented with the requirements of provincial road transportation agencies. In general, the applicators seemed to have a good sense of the conditions under which the dust suppressant would perform effectively.

Dust suppressant users were the main source of information on the factors that influence the effectiveness of various dust suppressants, and how they performed under the specific conditions of their site. Many users have applied other dust suppressants in past seasons, and could also provide an objective comparative assessment of the various products used. Users provided information on their total seasonal cost on a per square meter basis for dust suppression.

The information collected in the telephone survey was used in the compilation of review parameters for traditional dust suppressants.

3.2 INFORMATION COLLECTION ON NON-TRADITIONAL DUST SUPPRESSANTS

Purpose

Non-traditional dust suppressants were investigated to provide information on alternatives to traditional agents, particularly petroleum based products.

Methodology

The scope of the information search involved contacting the suppliers of non-traditional dust suppressants to obtain information on intended use, technical effectiveness and costs.

The Ministry has defined a list of non-traditional dust suppressants that are currently under review by the MOE for use in Ontario, presented in Table 3.2. Many of these are not recommended for road application; they are used for controlling dust emissions from stock piles of materials (e.g. coal and road shoulders). Several of these materials fall into categories already covered by traditional dust suppressants and therefore would perform similarly, and would result in similar impacts to the environment.

Only two dust suppressants were identified that could be considered alternatives to these already in use in Ontario. These are:

- Soil Sement.
- Perma Zyme.

Each of the above was reviewed.

Table 3.2
Non-Traditional Dust Suppressants

Name	Supplier	Category
Entac	Entac Canada	Tall oil resin emulsion.[1]
Soil Sement	Midwest Inc. Supply Inc.	Polymer based emulsion.
Petro Tac	Syn Tech Products Corp.	Oil asphalt emulsion.[1]
Hercobind TKW	Hercules Canada Inc.	Petroleum resin.[1]
Rerefined Oil	Da Lee Dust Control	Oil.[1]
Hoe S2745	Hoechst Canada	Acid/amine/acetate/water emulsion.[2]
Bond All	NorJohn Ltd.	Petroleum based resin emulsion.[1]
Trisal	Sifto Canada Inc.	Brines.[1]
Dust Ban - 8A04 & 8A09 - II - 8A07	Alchem Inc.	 Organic surfactant water additive.[2] Organic polymer containing petroleum distillate.[2] Sulphonate form.[2]
Dust Bloc - 120 - 355 - 520 - 525 - 635	Chemlink	 Surfactant.[2] Magnesium chloride brine.[1,2] Latex based emulsion.[2] Acrylic emulsion.[2] Calcium sodium lignosulphonate.[1]
Coherex	Dust Lock Inc.	Petroleum resin.[1]
Dustop	Diachem	Sodium lignosulphonate.[1]
Enduraseal	International Dust Control	Tall oil emulsion.[1]
Perma Zyme	Global Enzymes Inc.	Enzyme/sugar/surfactant

Notes:

1. Category covered under traditional dust suppressants.
2. For dust suppression on materials piles, road shoulders or material transfer ponds. Not recommended for use on roads.

Results

Information on non-traditional dust suppressants was used in the assessment of alternatives to oils as dust suppressants, presented in Chapter 5. A summary of information on these suppressants is presented in Table 3.3.

Table 3.3
Alternatives to Traditional Dust Suppressants

Material	Description	Cost
Soil Sement	• Polymer based emulsion, penetrates surface to form ductile crust. • Used diluted 9 parts water to 1 part product. • Reportedly performs well in sandy soils, or with high fines content, and is insensitive to traffic load. • Application rates of about 0.3 L/m^2 diluted product.	$0.06/L of diluted product, or $0.02/$m^2$ excluding transportation and application.
Perma Zyme	• Enzyme/sugar/surfactant mixture forms water resistant matrix within soil that resists erosion due to water, frost, tire abrasion. • Used diluted 100 parts water to 1 part product, mixed into soil at 0.33 L/m^3. Follow-up applications are sprayed. • Binding effect is improved with increased fines content. Performance insensitive to climate and rain, and traffic loads. • Reportedly lasts several years after application.	$2.75 per m^3 of treated soil.

3.3 LITERATURE SEARCH FOR INFORMATION ON TRADITIONAL DUST SUPPRESSANTS

Purpose

A major component of the retrieval of technical information on the performance and environmental impacts of traditional dust suppressants was the execution of an extensive literature review. The main focus of the literature review were field studies that had examined the effectiveness, and persistence, migration and other environmental impacts resulting from application of the dust suppressant.

Methodologies

Although some literature was obtained from other sources, the largest portion was identified using the CAN/OLE^R service of the Canadian Institute for Scientific and Technical Information. This service allows an on-line search of more than 25 computerized databases. The primary databases used in this study included:

1. The National Technical Information Service (NTIS), a catalogue of U.S. government-sponsored research, development and engineering reports (over 1.2 million references.)

2. The Engineering Index (EI) and the Engineering Index-Meetings (EIM) produced by Engineering Information Inc., which cover all aspects of engineering and related technologies including over 2,000 technical conferences each year (over 2.3 million references).

3. The TRANSCAT database, produced by the Library and Information Centre of Transport Canada, which contains the Transport Canada Library Network's holdings, including all non-restricted Transport Canada documents and reports from various other sources related to transportation and management.

4. The ELIAS database, produced by the Environment Canada Departmental Library, and corresponds to the collections of more than 20 libraries participating in the Environment Canada Departmental Library network.

Other literature sources included reports provided by the Ministries of the Environment and Transportation, and by the suppliers of dust suppressants. In addition, where information on the environmental impacts of dust suppressant application was limited, additional literature were reviewed on the persistence and migration of the contaminants present in the material. This information was obtained from:

- CH2M HILL in-house libraries in Canada and the U.S.
- U.S. EPA Water Engineering Research Library (WERL) Database.
- International Register of Potentially Toxic Chemicals (IRPTC) Databases, developed as part of the United Nations Environment Program (UNEP), and accessible through Health and Welfare Canada.

Results

Appendix A presents the list of reference sources reviewed for compilation of the review parameters list.

A number of field studies on the effectiveness on the traditional dust suppressants have been reported in the literature. However, a standardized procedure for reporting on effectiveness does not exist, and therefore, findings cannot be compared from study to study. Furthermore, many studies have not reported all of the site conditions that affected the performance of the test substance during the study, therefore conclusions on these factors could not be drawn for comparison purposes. Based on the literature information, supplemented with the telephone survey results, a general understanding of the conditions that reduce or increase the effectiveness of traditional dust suppressants could be developed, although a well defined set of control parameters could not be established.

Few studies have been carried out on the persistence and migration of dust suppressants in the environment that have been applied to surfaces. The environmental impacts were, therefore, assessed based on the behaviour of measured components and contaminants of the dust suppressant in the environment, as reported in the literature.

3.4 CHEMICAL ANALYSIS OF TRADITIONAL DUST SUPPRESSANTS

Purpose

In order to provide review parameters on the chemical composition of the traditional dust suppressants, a range of parameters were analyzed in a representative sample of each material.

Methodology

Samples of each dust suppressant were requested from the suppliers during the initial telephone survey. In order to obtain the most representative sample, suppliers were requested for samples of different production batches or product types, and these were composited for analysis. Table 3.4 presents the sources of each sample. Composite

Table 3.4
Source of Dust Suppressant Samples

Dust Suppressant	Source
Calcium chloride	Sample of one production batch provided by General Chemical Canada Ltd.
Oil field brine	One sample of oil field brine was provided by McKeggan Trucking Ltd. from their storage tanks. Storage tanks contain a mix of brines from a number of sources.
Road Binder	Two samples of Road Binder were provided by Domtar, one from their storage tanks, and the other, from their outdoor storage ponds.
Tembind	Temfibre provided one sample from each of seven different production batches of Tembind.
Dust Bond	Da-Lee provided one undiluted sample of Dust Bond.
DCS-225	NorJohn provided one undiluted sample of DCS-225.
Coke wash oil	NorJohn provided one sample of Petro Canada's Wash Oil A (coke wash oil).
Line wash oil	Petro Canada provided one sample of Dark Journal Oil (line wash oil).
Bunker fuel oil	Petro Canada provided one sample of bunker fuel oil.
Rerefined oil	Safety Kleen provided samples of three different grades of rerefined oil.

samples were split and a portion sent to a second laboratory for acute toxicity testing (discussed in Section 3.5). With the exception of Dust Bond and DCS-225, all samples were undiluted for testing. Dust Bond and DCS-225 were diluted with deionized water to achieve the recommended strength for road application and analytical results reported were for diluted samples.

All samples were analyzed in duplicate by Canviro Analytical Laboratories Ltd. (CALL) in Kitchener, Ontario. The list of parameters analyzed included conventional parameters and metals, as well as those contaminants specific to the nature and source of the dust suppressant. Table 3.5 presents the selected contaminant groups that were analyzed in each type of dust suppressant while Table 3.6 presents the specific contaminants analyzed in each contaminant group.

Table 3.5
Selected List of Parameters Measured in Traditional Dust Suppressants

Dust Suppressant	Parameters
All dust suppressants	Conventional parameters Metals
Brines	Chloride Sulphate
Pulping liquors	Total phenols Dioxin and furan compounds
Petroleum based products	Volatile organic compounds (VOC) Polynuclear aromatic hydrocarbons (PAH)
Virgin oils	Volatile organic compounds (VOC) Polynuclear aromatic hydrocarbons (PAH)
Rerefined oil	Volatile organic compounds (VOC) Polynuclear aromatic hydrocarbons (PAH) PCBs

Results

Raw data results for the duplicate samples provided by Canviro are provided in Appendix C. The results are included in the review parameters report for each dust suppressant, and also in the Chapter 6 Summary section.

Table 3.6
List of Chemicals Analyzed

Volatile Organic Compounds	Metals
Chloromethane	Aluminum
Vinyl Chloride	Boron
Bromomethane	Barium
Chloroethane	Beryllium
Trichlorofluoromethane	Cadmium
Acrolein	Calcium
1,1-Dichloroethylene	Chromium
Methylene Chloride	Cobalt
Acrylonitrile	Copper
trans-1,2-Dichloroethylene	Iron
1,1-Dichloroethane	Lead
Methyl ethyl ketone	Magnesium
Chloroform	Manganese
Bromochloromethane	Vanadium
1,1,1-Trichloroethane	Zinc
Carbon Tetrachloride	Nickel
1,2-Dichloroethane	Silver
Benzene	Strontium
Trichloroethylene	Sodium
1,2-Dichloropropene	Arsenic
Bromodichloromethane	Selenium
2-Chloroethylvinyl ether	Mercury
cis-1,3-Dichloropropylene	**Polynuclear Aromatic Hydrocarbons**
trans-1,3-Dichloropropylene	Naphthalene
Toluene	Acenaphthylene
1,1,2-Trichloroethane	Acenaphthene
Tetrachloroethylene	Fluorene
Dibromochloromethane	Phenanthrene
Ethylene dibromide	Anthracene
Chlorobenzene	Fluoranthene
m&p Xylene	Pyrene

Table 3.6
List of Chemicals Analyzed

Volatile Organic Compounds	Polynuclear Aromatic Hydrocarbons
Ethylbenzene	Benzo (a) anthracene
Styrene	Chrysene
o-Xylene	Benzo (b) fluoranthene
Bromoform	Benzo (k) fluoranthene
1,1,2,2-Tetrachloroethane	Benzo (a) pyrene
1,3-Dichlorobenzene	Indeno (1,2,3-cd) pyrene
1,4-Dichlorobenzene	Dibenzo (a,h) anthracene
1,2-Dichlorobenzene	Benzo (ghi) perylene
Conventional Parameters	**Dioxins and Furans**
Ph	TCDD
Total solids	TCDF
BOD_5	PCDD
Total phosphorus	PCDF
Ammonia - nitrogen	H6CDD
Oil and Grease	H6CDF
PCBs	H7CDD
PCB-1242	H7CDF
PCB-1254	OCDD
PCB-1260	OCDF
Total PCB	

3.5 ACUTE TOXICITY TESTING

Purpose

Each of the dust suppressant samples provided by the suppliers, described in Table 3.4, were also sent to BAR Environmental Inc. for the purposes of establishing the aquatic toxicity of the dust suppressant to rainbow trout (Oncorhynchus mykiss) and Daphnia magna (water flea).

Methodology

All samples were assessed for their acute toxicity to trout and Daphnia using the procedures developed by the Ontario Ministry of the Environment. These included the 48 hour acute lethality test using Daphnia magna and the 96 hour acute lethality test using rainbow trout.

For those substances which readily dissolved in water, multiple concentrations of the test material were prepared by adding measured volumes of the test substance to the laboratory dilution. For those products that did not readily dissolve in water (including all oils), organic solvents were used to increase solubility. Three solvents, including methanol, acetone and triethylene glycol, were used at the maximum recommended rate of 0.5 mL of solvent per litre of dilution water. One product, Petro Canada Wash Oil A, dissolved in acetone but only at a very low concentration (<2,000 mg/L). Furthermore, oil droplets formed when the stock solution was added to the dilution water. As such, an alternate method of preparing the test solutions was developed as a result of discussions with Dave Poirier, Aquatic Biology Unit, Ministry of the Environment.

For those products that did not readily dissolve in water, tests were carried out on the water soluble fraction of the materials (i.e. that which would dissolve in water after an extended period of exposure). For these materials, test solutions having a nominal concentration of 10,000 mg/L product were prepared by adding 20 mL of product to 20 L of dilution water. The solutions were stored at 15 °C for 24 and 96 hours prior to testing. Oil-free compressed air was supplied during this time to provide gentle mixing of the solution. At the end of the storage period, the solution to be tested was removed from the test container by siphoning off the liquid and transferring this material to a new, clean test container.

Results

The report prepared by B.A.R. presenting detailed methodologies and results is provided in Appendix D. The toxicity results are presented in the review parameter reports for each traditional dust suppressant and also in the Chapter 6 Summary section of this report.

3.6 REVIEW OF BACKGROUND LEVELS, GUIDELINES AND OBJECTIVES FOR CONTAMINANTS

In most cases, information on sub-lethal effects and environmental impacts of traditional dust suppressants were not identified in the literature. Therefore, an approach was adopted to evaluate those components of interest that were above relevant limits set for the contaminants. For sub-lethal effects, contaminant levels were compared to guidelines and objectives for drinking water and aquatic life. For environmental

impacts, those contaminants exceeding soil background levels or soil clean-up criteria were evaluated in more detail.

It is important to note that this approach led to a very conservative assessment of both sub-lethal effects and environmental impacts. The actual levels of contaminant that would affect human or animal health, plant life, aquatic life or the environment under normal road application of dust suppressants would be significantly lower than those measured in the sample, due to dilution, evaporation, decay and adsorption. However, these levels were for the most part, unavailable.

Table 3.7 presents the guidelines, standards and objectives used in the study.

3.7 LITERATURE REVIEW FOR SUB-LETHAL EFFECTS OF TRADITIONAL DUST SUPPRESSANTS

Purpose

B.A.R. Environmental in Guelph carried out a literature search to identify the sub-lethal effects of the 10 dust suppressants and their components. The areas covered included sub-chronic/chronic toxicity, mutagenicity, reproductive toxicity, carcinogenicity, neurotoxicity, chronic feeding studies, and bioconcentration/bioaccumulation and dermal effects.

Methods

Relevant literature on the dust suppressants and contaminants of concern was identified from:

1. The in-house library at B.A.R.
2. The University of Guelph library.
3. The Ministry of the Environment libraries, including the following computer databases:

    - CESARS
    - CHEMINFO
    - MSDS
    - RTECS

Results

The literature search results were used in the preparation of review parameter reports for each of the traditional dust suppressants.

Table 3.7
Objectives, Guidelines and Standards Compared to Contaminants in Dust Suppressants

	Aquatic Life	Drinking Water	Soil Concentrations
Conventionals			
Ammonia	0.02 mg/L (unionized)[1]	n/a	
Chloride	n/a	250 mg/L[1,2]	
Phenols	1 µg/L[1]	2 µg/L[1]	
Metals			
Aluminum	5 - 100 µg/L[3,1]	200 µg/L[4]	n/a
Barium	n/a	1,000 µg/L[1,2]; 100 µg/L[5]	200 µg/g dry wt.[9]
Beryllium	11 - 1,100 µg/L[1]	0.2 µg/L[5]	4 µg/g dry wt.[9]
Boron	n/a	5,000 µg/L[1,2]	15 µg/g dry wt.[10]
Cadmium	0.2 µg/L[1]	5 µg/L[1,2]	4 µg/g dry wt.[10]
Calcium	n/a	no need to set numerical guidelines[7]	n/a
Chromium	100 µg/L[1]; 2 - 200 µg/L[3]	50 µg/L[1,2]	50 µg/g dry wt.[10]
Cobalt	n/a	n/a	25 µg/g dry wt.[10]
Copper	5 µg/L[1]; 2 - 4 µg/L[3]	1,000 µg/L[1,2]	100 µg/g dry wt.[10]
Iron	300 µg/L[1]	300 µg/L[1,2]	3.5%/wt.[10]
Magnesium	n/a	no need to set numerical guideline[7]	n/a
Manganese	n/a	100 µg/L[4]; 50 µg/L[1]; 500 µg/L[2]	700 µg/g dry wt.[10]
Nickel	25 µg/L[1]; 25 - 150 µg/L[3]	n/a	60 µg/g dry wt.[10]
Phosphorus	20 µg/L (algal growth); or 10 µg/L[1]	n/a	n/a
Potassium	n/a	n/a	n/a
Selenium	1 µg/L[2,3]; 100 µg/L[1]	10 µg/L[1,2]	2 µg/g dry wt.[10]
Sodium	n/a	200,000 µg/L[4]	n/a
Strontium	n/a	n/a	n/a
Vanadium	n/a	n/a	75 µg/g dry wt.[10]
Zinc	30 µg/L[1,3]	5,000 µg/L[1,2]	500 µg/g dry wt.[10]
Volatile Organic Compounds			
Benzene	300 µg/L[3]	10 µg/L[4]; 5 µg/L[2]	0.05 µg/g dry wt.[9]
Carbon Tetra-chloride	13 µg/L[3]	5 µg/L[2]	0.1 µg/g dry wt.[9]
Chloroform	2 µg/L[3]	350[1]; 5 µg/L[6]; 70 µg/L[8]	0.1 µg/g dry wt.[9]

Table 3.7
Objectives, Guidelines and Standards Compared to Contaminants in Dust Suppressants

	Aquatic Life	Drinking Water	Soil Concentrations
Volatile Organic Compounds (Cont'd)			
Ethylbenzene	700 µg/L[3]	2.4 µg/L[2]	0.1 µg/g dry wt.[9]
Methylene Chloride	98 µg/L[3]	1,750 µg/L[6]	0.1 µg/g dry wt.[9]
Methyl ethyl ketone	n/a	n/a	n/a
1,1,2-Trichloroethane	n/a	0.6 µg/L[6]	n/a
Toluene	300 µg/L[3]	24 µg/L[2]	0.1 µg/g dry wt.[9]
m-Xylene	n/a	30 µg/L[2]	0.1 µg/g dry wt.[9] (total xylenes)
o-Xylene	n/a	30 µg/L[2]	0.1 µg/g dry wt.[9] (total xylenes)
p-Xylene	n/a	30 µg/L[2]	0.1 µg/g dry wt.[9] (total xylenes)
PAH Compounds			
Acenaphthene	n/a	n/a	n/a
Benzo (a) anthracene	n/a	n/a	0.1 µg/g dry wt.[9]
Benzo (a) pyrene	n/a	0.2 µg/L[4] (total)	0.1 µg/g dry wt.[9]
Benzo (b) fluoranthene	n/a		0.1 µg/g dry wt.[9]
Benzo (ghi) perylene	n/a		n/a
Benzo (k) fluoranthene	n/a		0.1 µg/g dry wt.[9]
Fluoranthene	n/a		n/a
Indeno (1,2,3cd) pyrene	n/a		0.1 µg/g dry wt.[9]
Chrysene	n/a	n/a	n/a
Dibenzo (a,h) anthracene	n/a	n/a	0.1 µg/g dry wt.[9]
Fluorene	n/a	n/a	n/a
Naphthalene	n/a	n/a	0.1 µg/g dry wt.[9]

Table 3.7
Objectives, Guidelines and Standards Compared to Contaminants in Dust Suppressants

	Aquatic Life	Drinking Water	Soil Concentrations
PAH Compounds			
Phenanthrene	n/a	n/a	0.1 µg/g dry wt.[9]
Pyrene	n/a	n/a	0.1 µg/g dry wt.[9]

Notes:

1. Ontario Ministry of the Environment, 1984. Water Management Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment.
2. Health and Welfare Canada, 1987. Canadian Guidelines for Drinking Water Quality.
3. Environment Canada & Health and Welfare Canada, 1991. How Safe is Our Water?
4. World Health Organization, 1984. Guidelines for Drinking-Water Quality. Volume 2. Health Criteria and other supporting information.
5. U.S.S.R. Cited from W.H.O. literature.
6. E.P.A. Cited from W.H.O. literature.
7. Health and Welfare Canada. 1991. Personal Communication.
8. Cited from M.O.E. literature.
9. Canadian Council of Ministers of the Environment, 1991. Interim CCME Environmental Quality Criteria for Contaminated Sites, Final Draft. These values are interim assessment criteria and are to be considered background or recommended detection limit values.
10. Contaminant guidelines representing upper limits of normal concentrations in Ontario surface soil, Guidelines For the Decommissioning of Clean-up of Sites in Ontario, MOE, 1989.

Chapter 4
SUMMARY OF REVIEW PARAMETERS

Review parameter reports for each of the ten traditional dust suppressants are presented in Appendix E. Review parameters are summarized on an aggregate basis in the following sub-sections.

4.1 COSTS

Table 4.1 presents a summary of reported costs for traditional dust suppressants, broken down according to product cost, transportation cost, application cost and total cost to various users. Note that costs for Tembind are given per tonne. Since the density of a 25% solution was unknown, these costs could not be converted to a per litre basis.

Table 4.1
Breakdown of Dust Suppressant Application Cost Components[1]

Dust Suppressant	Product Cost	Transportation Cost	Application Cost	Total Cost	Seasonal Cost[2]	
					Typical	Maximum
Calcium chloride (35% solution)	$0.07/L	$0.12-$0.23/L	$0.003-0.009/L	$0.19-0.31/L	$0.10-0.30/m^2	$0.55/m^2
Oil field brine	$0	-[3]	$0.02-0.04/L	$0.02-0.04/L	$0.09-0.40/m^2	>$5.00/m^2
Tembind (25% solution)	$33/t	$5-9/t	$55/t	$95/t	$0.1-0.2/m^2	$0.25/m^2
Road Binder	$0/L	-[3]	<$0.01/L[4]	<$0.01/L[4]	$0.01-0.02/m^2	$0.04/m^2
DCS-225 (3:1)	$0.07/L	-[3]	$0.10/L	$0.17/L	$0.61/m^{2,5}	-
Dust Bond (5:1)	$0.08/L	-[3]	$0.09/L	$0.19/L	$1.03/m^{2,5}	-
Virgin oils	$0.28-0.40/L	-[3]	$0.10-0.22/L	$0.38-0.50/L	$0.50/m^2	$1.00/m^2
Re-refined oils	$0.30/L	-[6]	-[6]	-[6]	-[6]	-[6]
Resurfacing road	-	-	-	-	$10/m^2	-

Notes:

1. All costs are in $1991 and do not include G.S.T.
2. As reported in study survey of users, reported application rates and frequency, unless otherwise noted.
3. Included in application cost.
4. These figures not precisely known since municipalities using Road Binder are located reasonably close to the Domtar plant and frequently use their own equipment for transport and application.
5. Based on recommended application rates.
6. Rerefined oils are not currently used as dust suppressants.

Road Binder is provided free of charge to users and consequently, is the least expensive dust suppressant on a seasonal basis. However, this material is generally only used on municipal roads with low traffic, primarily in the Trenton, Ontario area.

Oil field brine is also provided free of charge to the applicator. The total unit cost of $0.02-0.04/L of this material makes it least expensive after Road Binder. However, application rates and frequencies result in seasonal costs of $0.09-0.40/m^2, comparable to calcium chloride and Tembind. One industrial user of oil field brine reported to be re-applying every two weeks, resulting in the highest seasonal cost per unit area reported for any dust suppressant.

Unit costs of DCS-225 and Dust Bond at $0.17 and $0.19/L, respectively, are about 50 percent higher than calcium chloride solution. In addition, at the recommended application rates, typical seasonal costs greater than $0.61/m^2 are highest of all dust suppressants.

Virgin oils and rerefined oils are the highest priced dust suppressant materials, at $0.28-0.40/L. However, at application rates reported to be effective, seasonal costs at $0.50/m^2 are less than those of DCS-225 and Dust Bond, but typically higher than all other dust suppressants. Oil users report that the higher costs of oil are warranted because alternative dust suppressants need much more frequent application to be effective under their particular site conditions, leading to significantly higher costs.

The cost of dust suppression is compared to the cost for paving roads in Table 4.1. Paving is approximately 10 times more costly than seasonal oil applications at typical rates.

4.2 TECHNICAL EFFECTIVENESS

Table 4.2 presents a summary of technical effectiveness for the traditional dust suppressants.

In general, the traditional dust suppressing agents can be divided into three groups related to the factors that affect their performance; brines, pulping liquors and petroleum based products.

Brines require an evenly graded surface soil composition with 2 to 12 percent silt content. Silt content higher than this will prevent surface binding and increase potholing, while lower fines and porous soil will result in runoff during rainfall and also reduce binding effects. The performance of brines is moisture dependent, and a relative humidity of greater than 50 percent is necessary. In general, brines are not used on roads with heavy or high volume traffic, because their lifetime is shortened and frequent application is necessary.

Table 4.2
Overall Comparison of Factors Affecting Performance of Traditional Dust Suppressants

Product Name	Technical Effectiveness According to:												
	Traffic					Surface Soil Composition (top 3 cm)				Weather			Effect by Maintenance Grading	General Comment
	Volume (ADT)[1]			Weight		Fines (%) <75 μm[2]								
	<100	<250	>250	Autos	Trucks	0 - 2	2 - 8	8 - 20	>20	Rain	Humid RH[3] >50%	Dry RH[3] <20%		
Dust Bond	Good	Fair	Poor	Good	Poor	Fair	Good	Fair	Fair to poor	Poor to Fair	Fair	Fair to Good	Poor	Sensitive to high traffic volume and weight, and sand. Poor gradability. Slippery when wet.
DCS-225	Good	Fair	Poor	Good	Poor	Fair	Good	Fair	Fair to poor	Poor to Fair	Fair to Good	Fair to Good	Poor to Fair	Sensitive to high traffic volume and weight, rain and sand. Poor gradability; surface crust destroyed. Will leach out in rain.
Tembind	Good	Fair	Poor to Fair	Good	Poor	Poor	Good	Good	Fair	Poor	Fair	Good	Poor	Should be applied in layers mixed into the surface. Sensitive to high traffic volume and weight, rain and sand. Insensitive to high fines content. Most effective in dry climate.
Road Binder	Good	Fair	Poor	Good	Poor	Poor	Good	Good	Fair	Poor	Fair	Good	Poor	Short lifespan. Sensitive to traffic, weight, volume, and rain. Insensitive to high fines content. Most effective in dry climates.
Calcium Chloride	Very Good	Good	Fair to Good	Very Good	Poor to Fair	Poor	Very Good	Fair	Fair to poor	Poor	Good	Fair	Fair to Good	Sensitive to high traffic volume and weight, rain, high sand or fines content. Will leach out of sand during rain. Some humidity required for effectiveness.
Oil Field Brine	Good	Fair	Poor	Good	Poor	Poor	Good	Poor	Poor	Poor	Good	Poor to Fair	Poor	Best suited to low volume auto traffic. Sensitive to fines, sand, and rain. Poor gradability. Some humidity required for effectiveness.
Virgin Oils	Very Good	Very Good	Good to Very Good	Very Good	Good	Good	Very Good	Fair to Good	Fair to poor	Good	Good	Good	Fair to Good	Combination of very high fines and rain will cause pot holing and slipperiness. Effective on sand.

Note:

1. Average daily traffic.
2.

Particle Type	Range (μm)
Clay	<2.0
Silt	2-50
Very fine sand	50-100
Fine sand	350-500
Coarse sand	500-1,000
Very coarse sand	1,000-2,000
Fine gravel	2,000-4,750
Coarse gravel	>4,750

3. Relative humidity.

In contrast to brines, pulping liquors perform optimally in controlling dust and stabilizing road surfaces in arid conditions. These agents are water soluble, and rainfall will result in leaching of material. Pulping liquors are relatively insensitive to the fines content of surface materials, but will not perform well in very porous soils. These liquors are rarely used in areas with heavy or high volume traffic, such as industrial yards, as they do not perform effectively under these conditions.

Petroleum products, including virgin oils and emulsions, perform optimally on well graded surfaces, with a percentage of fines less than 8 percent. Fines content higher than this will result in potholing, particularly in wet weather. However, they are the only group whose performance is fair to good on porous or sandy soils with low fines content. Virgin oils have been used in areas where other traditional dust suppressants have not been effective because of soil porosity, high traffic weights and volumes, or unusual surface conditions (e.g. horse arenas). Petroleum emulsions are reportedly not as effective as virgin oils in controlling dust.

4.3 CHEMICAL CHARACTERISTICS

Table 4.3 presents the main components of each of the ten traditional dust suppressants. Calcium chloride is the main salt component of calcium chloride solution and flake and oil field brine, although oil field brine also contains magnesium and sodium salts.

Solids in both pulping liquors contain lignins. In Tembind, lignin is one of the main components, while remaining components are primarily biodegradable sugars and reducing bodies. In Road Binder, there is a large inorganic component (22 percent) in addition to the biodegradable component.

Concentrated petroleum based emulsions include a large water component. DCS-225 is 80 to 90 percent water, and the remaining portion is fatty acids. Dust Bond is 40 percent water and emulsifier, and 60 percent petroleum resin.

Virgin and rerefined oil products are 90 to 100 percent hydrocarbons.

Tables 4.4 to 4.7 summarize the results of chemical analyses carried out on samples of the 10 traditional dust suppressants for this study.

Because the oil products and Dust Bond were immiscible in water, BOD_5 could not be measured. However, oil products are biodegradable in the environment and a significant BOD_5 value is assumed. Thus, based on the BOD_5 results presented in Table 4.4, all dust suppressants except brines exhibit a significant biodegradable component. Ammonia-nitrogen levels in oil field brine, Tembind, Road Binder and Dust Bond, ranging from 30 to 1,150 mg/L, and phenolics in Road Binder (14,900 µg/L) would also contribute to the BOD level.

Table 4.3
Composition of Traditional Dust Suppressants

Agent	Components
Calcium Chloride	Solution - 35% $CaCl_2$, 65% water Flake - 77% $CaCl_2$, 23% water
Oil Field Brine	Calcium - 34,000 to 43,000 mg/L Magnesium - 2,850 to 10,000 mg/L Sodium - 6,670 to 38,000 mg/L Chloride - 157,000 to 210,000 mg/L
Road Binder	Total solids - 232,000 mg/L (23 percent) Composition of solids: • Inorganic cations - 18.4% • Inorganic anions - 3.7% • Carboxylates - 36.4% • Polysaccharides - 6.2% • Lignin/lignosulphonates - 7.9% • Resin & fatty acids - 0.1% • Phenolics/extractives - 0.7% • Suspended matter - 18.3%
Tembind	Total solids - 281,000 mg/L (25 percent) Composition of solids: • Lignin - 65% • Reducing bodies - 22% • HPLC sugars - 17% • Methyloxyl - 7.1% • Nitrogen - 5% • Sulphur - 6%
DCS-225	Undiluted: • Water - 80 - 90% • Bitumens - 0.5 - 1.5% • Fatty acids - 8.6 - 19.5%
Dust Bond	Undiluted: • Petroleum resin (distillate) - 60% • Emulsifier and water - 40%
Line Wash Oil[1]	• Severely treated paraffinic and solvent refined naphthenic oils (90 to 95%) • Additives (5 to 10%)
Coke Wash Oil[1]	• Complex mixture of aromatic/aliphatic hydrocarbons (100%)
Bunker Fuel Oil[1]	• Complex mixture of aromatic/aliphatic hydrocarbons ($\geq$97%) • Sulphur (3%)
Rerefined Oil	• Rerefined lubricating oils without additives (100%)

Notes:

1. Products from Petro Canada. Composition may vary in products from other oil companies.

Table 4.4
Summary of Conventional Contaminants and Metals in Traditional Suppressants[1]

	Units	Calcium Chloride (35% Solution)	Oil Field Brine	Tembind	Road Binder	DCS-225 (3:1)	Dust Bond (5:1)	Line Wash Oil[2]	Coke Wash Oil[3]	Bunker Fuel[4]	Rerefined Oil[5]
Conventional Parameters											
pH		8.8	5.8	4.7	8.7	8.6	4.9	5.2	7.8	6.05	9.7
Total Solids[6]	mg/L	492,500	312,000	281,000	232,000	59,500	119,000	690,000	562,000	480,000	732,000
BOD_5	mg/L	<300[7]	<300	24,830	114,690	23,000	NA[8]	NA[8]	NA[8]	NA[8]	NA[8]
Ammonia-N	mg/L	<500	174	1,150	177	<20	30	<500	<500	<500	<500
Total Phosphorus	mg/L	0.10	0.24	106	170	153	102	-[9]	30.8	-	17
Oil & Grease	mg/L	<1.0	<1.0	810	6,900	60,600	138,000	-	-	-	-
Phenols	µg/L	-	-	<1	14,900	-	-	-	-	-	-
Chloride	mg/L	307,500	157,500	-	-	-	-	-	-	-	-
Sulphate	mg/L	<148	<148	-	-	-	-	-	-	-	-
Metals											
Aluminum	mg/L	<0.05	0.52	3.82	3.44	<0.05	0.135	2	<2	10	4
Boron	mg/L	7.48	6.49	0.465	2.02	0.06	0.065	5	5.5	12	7.5
Barium	mg/L	25.9	0.23	0.365	4.45	<0.01	<0.01	<2	<2	<2	<2
Beryllium	mg/L	0.065	0.008	<0.005	<0.005	<0.005	<0.005	<0.5	<0.5	<0.5	<0.5
Cadmium	mg/L	0.034	<0.012	0.034	0.034	<0.012	<0.012	<0.2	<0.2	<0.2	<0.2
Calcium	mg/L	133,000	38,000	156.5	6.34	5.35	3.51	<5	<5	10	5
Chromium	mg/L	0.045	<0.02	0.085	0.03	<0.02	<0.02	<0.5	<0.5	<0.5	<0.5
Cobalt	mg/L	0.105	<0.03	<0.03	<0.03	<0.03	<0.03	<0.5	<0.5	<0.5	<0.5
Copper	mg/L	0.18	0.035	0.305	0.16	0.04	0.0025	<0.5	<0.5	<0.5	<0.5

Table 4.4
Summary of Conventional Contaminants and Metals in Traditional Suppressants[1]

	Units	Calcium Chloride (35% Solution)	Oil Field Brine	Tembind	Road Binder	DCS-225 (3:1)	Dust Bond (5:1)	Line Wash Oil[2]	Coke Wash Oil[3]	Bunker Fuel[4]	Rerefined Oil[5]
Iron	mg/L	1.49	6.16	5.61	2.49	0.615	1.69	<0.5	<0.5	4	<0.5
Lead	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<1	<1	<1
Magnesium	mg/L	21.35	2,845	31.35	70.55	1.0	0.77	<5	2	5	2
Manganese	mg/L	0.065	0.59	14.7	5.67	<0.01	0.015	<0.5	<0.5	<0.5	<0.5
Vanadium	mg/L	2.44	0.41	<0.01	<0.01	<0.01	<0.01	<0.5	<0.5	18	<0.5
Zinc	mg/L	0.16	0.3	1.2	4.16	0.01	0.05	2	<1	4.5	<1
Nickel	mg/L	0.04	<0.02	0.21	0.105	<0.02	<0.02	3	<0.5	12.5	<0.5
Silver	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.5	<0.5	<0.5	<0.5
Strotium	mg/L	30.9	690	0.695	0.255	0.025	0.015	<0.5	<0.5	<0.5	<0.5
Sodium	mg/L	2,667	6,670	<5	16,470	243	<5	30	10	50	10
Arsenic	mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.2	<0.2	<0.2	<0.2
Selenium	mg/L	<0.01	<0.01	0.02	0.025	<0.01	<0.01	<0.2	<0.1	<0.2	<0.1
Mercury	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.02	<0.02	<0.02	<0.02

Notes:

1. Averaged results for duplicate samples of each dust suppressant.
2. Dark Journal Oil from Petro Canada.
3. Wash Oil A from Petro Canada.
4. Bunker Fuel Oil from Petro Canada.
5. Breslube Oil from Safety-Kleen.
6. Total solids refers to total residue remaining after sample is evaporated in an oven at 103 to 105 ^{o}C for $\geq$ 1 hour.
7. <# - Less than analytical detection limit.
8. NA - Sample was insoluble in water, therefore BOD_5 analyses not possible.
9. "-" - Not included in analytical program for this substance.

Table 4.5
Summary of Polynuclear Aromatic Hydrocarbon Compounds in Petroleum Based Dust Suppressants[1]

	Units	DCS-225 (3:1)	Dust Bond (5:1)	Line Wash Oil[2]	Coke Wash Oil[3]	Bunker Fuel[4]	Rerefined Oil[5]
Polynuclear Aromatic Hydrocarbons							
Naphthalene	µg/L	682	85.6	<6.4	1,710	155,000	17,800
Acenaphthylene	µg/L	<3.2	<3.2	<6.4	<80	<6.4	<80
Acenaphthene	µg/L	61.25	41.2	<12.8	38,500	<12.8	8,650
Fluorene	µg/L	134.5	103.5	<6.4	<80	187,500	19,200
Phenanthrene	µg/L	286.5	1,215	<11.2	<140	465,000	124,500
Anthracene	µg/L	<6.4	<6.4	<12.8	<160	<12.8	<160
Fluoranthene	µg/L	<4.8	2,975	<9.6	4,010	<9.6	20,150
Pyrene	µg/L	<3.2	22,300	<6.4	6,140	11,300	63,450
Benzo (a) anthracene	µg/L	<4	<4	<8.0	<100	<8.0	12,900
Chrysene	µg/L	<5.6	2,775	<11.2	<140	<11.2	23,850
Benzo (b) fluoranthene	µg/L	<5.6	2,275	<11.2	<140	<11.2	<140
Benzo (k) fluoranthene	µg/L	<5.6	(6)	<11.2	<140	<11.2	<140
Benzo (a) pyrene	µg/L	55.15	3,455	<9.6	<140	<9.6	9,275
Indeno (1,2,3-cd) pyrene	µg/L	<8.8	<8.8	<17.6	<220	<17.6	3,295
Dibenzo (a,h) anthracene	µg/L	<6.4	<6.4	<12.8	<160	<12.8	<160
Benzo (ghi) perylene	µg/L	<7.2	5,115	<14.4	<180	<14.4	5,755

Notes:

1. Averaged results for duplicate samples.
2. Dark Journal Oil from Petro Canada Inc.
3. Wash Oil-A from Petro Canada Inc.
4. Provided by Petrol Canada Inc.
5. Breslube Oil from Safety Kleen Inc.
6. Benzo (b) and Benzo (k) fluoranthene co-eluted, therefore result is reported as a total.

Extractable oil and grease levels were also significant in all dust suppressants, except the brines.

Low levels of metals, excluding main component salts, were detected in all of the dust suppressants. In general, these levels were lower or only slightly above selected guidelines and objectives for drinking water quality. Bunker fuel had the highest level of metals.

Table 4.6
Summary of Volatile Organic Compounds in Petroleum Based Dust Suppressants

Volatile Organic Compounds	Units	DCS-225 (3:1)	Dust Bond (5:1)	Line Wash Oil[2]	Coke Wash Oil[3]	Bunker Fuel[4]	Rerefined Oil[5]
Chloromethane	µg/L	<180[6]	<180	<360	<360	<360	<360
Vinyl chloride	µg/L	<250	<250	<500	<500	<500	<500
Bromomethane	µg/L	<100	<100	<200	<200	<200	<200
Chloroethane	µg/L	<80	<80	<160	<160	<160	<160
Trichlorofluoromethane	µg/L	<175	<175	<350	<350	<350	<350
Acrolein	µg/L	<110	<110	<220	<220	<220	<220
1,1-Dichloroethylene	µg/L	<80	<80	<160	<160	<160	<160
Methylene chloride	µg/L	1,710	9,175	<180	<180	<180	<180
Acrylonitrile	µg/L	<105	<105	<210	<210	<210	<210
trans-1,2-Dichloroethylene	µg/L	<35	<35	<70	<70	<70	<70
1,1-Dichloroethane	µg/L	<25	<25	<50	<50	<50	<50
Methyl ethyl ketone	µg/L	<55	<55	750	<110	70,500	2,485
Chloroform	µg/L	<20	<20	182	<40	9,200	985
Bromochloromethane	µg/L	<10	<10	<20	<20	<20	<20
1,1,1-Trichloroethane	µg/L	<25	<25	<50	<50	<50	<50
Carbon Tetrachloride	µg/L	<35	<35	180	<70	<70	<70
1,2-Dichloroethane	µg/L	<15	<15	<30	<30	<30	<30
Benzene	µg/L	<20	<20	65	<40	20,500	<40
Trichloroethylene	µg/L	<95	<95	<190	<190	<190	<190
1,2-Dichloropropylene	µg/L	<10	<10	<20	<20	<20	<20
Bromodichloromethane	µg/L	<10	<10	<20	<20	<20	<20
2-Chloroethylvinyl ether	µg/L	<20	<20	<40	<40	<40	<40
trans-1,3-Dichloropropylene	µg/L	<15	<15	<30	<30	<30	<30
cis-1,3-Dichloropropylene	µg/L	<25	<25	<50	<50	<50	<50
Toluene	µg/L	390	185	155	<22.5	102,850	3,285
1,1,2-Trichloroethane	µg/L	<15	<15	<30	<30	<30	<30
Tetrachloroethylene	µg/L	<40	<40	<80	<80	<80	<80
Dibromochloromethane	µg/L	<10	<10	<20	<20	<20	<20
Ethylene dibromide	µg/L	<30	<30	<60	<60	<60	<60
Chlorobenzene	µg/L	<10	<10	<20	<20	<20	<20
m&p-Xylene	µg/L	1,003	152.5	98.0	39.5	202,250	690

Table 4.6
Summary of Volatile Organic Compounds in Petroleum Based Dust Suppressants

Volatile Organic Compounds	Units	DCS-225 (3:1)	Dust Bond (5:1)	Line Wash Oil[2]	Coke Wash Oil[3]	Bunker Fuel[4]	Rerefined Oil[5]
Ethyl benzene	µg/L	265	41	32	15	47,350	437.5
Styrene	µg/L	<20	<20	<40	<40	<40	<40
o-Xylene	µg/L	512.5	65.5	<40	20.5	97,150	1,550
Bromoform	µg/L	<15	<15	<30	<30	<30	<30
1,1,2,2-Tetrachloroethane	µg/L	<25	<25	<50	<50	<50	<50
1,3-Dichlorobenzene	µg/L	<10	<10	<20	<20	<20	<20
1,4-Dichlorobenzene	µg/L	<5	<5	<10	<10	<10	<10
1,2-Dichlorobenzennee	µg/L	<20	<20	<40	<40	<40	<40

Notes:

1. Averaged results for duplicate samples.
2. Dark Journal Oil from Petro Canada Inc.
3. Wash Oil-A from Petro Canada Inc.
4. Provided by Petro Canada Inc.
5. Breslube Oil from Safety Kleen Inc.
6. <# - Below the analytical detection limit.

Table 4.5 compares polynuclear aromatic hydrocarbon (PAH) concentrations measured in petroleum based products. With the exception of line wash oil, PAH compounds were detected in all of these products. In coke wash oil and bunker fuel oil, only lighter weight, more volatile compounds were detected. In the two petroleum resins and rerefined oil, a range of these compounds were detected, including the most heavy and persistent molecules. Concentrations ranged from less than 300 µg/L for PAH compounds in DCS-225, to greater than 100,000 µg/L, for individual compounds in bunker fuel and rerefined oil.

The volatile organic compound (VOC) levels in the six petroleum products are presented in Table 4.6. All of these agents contain VOC compounds, in levels ranging from 20 µg/L to 200,000 µg/L. Compounds commonly detected include methylene chloride, methyl ethyl ketone, chloroform, toluene, m&p-xylenes and o-xylene. Benzene was detected in line wash oil (70 µg/L) and bunker fuel oil (20,500 µg/L). Levels of VOCs measured in bunker fuel were generally one to two orders of magnitude higher than in all other dust suppressants.

A complete scan of dioxin and furan compounds was carried out on Domtar Road Binder and Tembind pulping liquors. Results are presented in Table 4.7 and 4.8. Total toxic equivalencies (TEQ) of dioxins and furans ranged from 0.023 to 0.029 ng TEQ/L in Road Binder, and 0.003 to 0.025 ng TEQ/L in Tembind.

Table 4.7
Summary of Dioxin and Furan Compounds in Pulping Liquors

	Road Binder				Tembind				Lab Blank (ng/L)	MDL Blank (ng/L)
	Sample A (ng/L)	MDL for A (ng/L)	Sample B (ng/L)	MDL for B (ng/L)	Sample A (ng/L)	MDL for A (ng/L)	Sample B (ng/L)	MDL for B (ng/L)		
T4CDD	<	0.600	<	0.300	<	1.400	<	1.700	<	0.082
T4CDF	<	0.470	<	0.240	<	1.100	<	1.300	<	0.064
P5CDD	<	0.074	<	0.330	<	1.700	<	2.200	<	0.074
P5CDF	<	0.270	<	0.230	<	1.200	<	1.600	<	0.052
H6CDD	<	0.850	<	0.570	<	2.600	<	4.000	<	0.154
H6CDF	<	0.670	<	0.450	<	2.100	<	3.100	<	0.122
H7CDD	TR	2.700	TR	2.200	TR	2.200	<	9.900	<	0.177
H7CDF	<	1.500	<	2.000	<	1.200	<	2.700	<	0.097
O8CDD	1.800	1.500	1.400	1.500	2.900	1.500	3.200	2.000	<	0.176
O8CDF	<	1.400	<	1.400	<	1.400	<	1.800	<	0.158
% Recovery of Surrogates										
C13-T4CDD	48		49		47		38		80	
C13-P4CDD	52		45		44		38		80	
C13-H6CDD	44		48		52		37		75	
C13-H7CDD	65		59		83		57		65	
C13-O8CDD	58		53		123		76		50	

Notes:

MDL - Method detection limit.
< - Less than detection limit.
TR - Trace amount detected.

Table 4.8
Toxicity Equivalents of Dioxin and Furan Compounds in Road Binder and Tembind

Dioxins and Furans	I.T.E.F.	Road Binder		Tembind	
		Sample A TEQ (ng/L)	Sample B TEQ (ng/L)	Sample A TEQ (ng/L)	Sample B TEQ (ng/L)
T4CDD	1.000	0.000	0.000	0.000	0.000
P5CDD	0.500	0.000	0.000	0.000	0.000
H6CDD	0.100	0.000	0.000	0.000	0.000
H7CDD	0.010	0.027	0.022	0.022	0.000
O8CDD	0.001	0.0018	0.0014	0.0029	0.0032
T4CDF	0.100	0.000	0.000	0.000	0.000
P5CDF	0.500	0.000	0.000	0.000	0.000
H6CDF	0.100	0.000	0.000	0.000	0.000
H7CDF	0.010	0.000	0.000	0.000	0.000
O9CDF	0.001	0.000	0.000	0.000	0.000

Notes:

I.T.E.F. - International toxicity equivalency factor
TEQ - Toxicity equivalents

Rerefined oil was analyzed for PCBs. Results are presented in Table 4.9. None of these compounds were detected in the sample.

Table 4.9
Summary of PCBs in Rerefined Oils

Parameter	Rerefined Oil[1]
PCB-1242	<120 µg/L
PCB-1254	<256 µg/L
PCB-1260	<256 µg/L

Notes:

1. Breslube Oil provided by Safety Kleen.

4.4 ACUTE TOXICITY AND SUB-LETHAL EFFECTS

Tables 4.10 and 4.11 present results of aquatic toxicity tests carried out on samples of the traditional dust suppressants.

Table 4.10
Summary for Acute Toxicity Testing Results for Traditional Dust Suppressants (Excluding Oils)

Dust Suppressant	Test Species				
	Rainbow Trout (96 h LC50)		Daphnia magnia (48 h LC50)		
	Concentration (mg/L)	95% Confidence Interval (mg/L)	Concentration (mg/L)	95% Confidence Interval (mg/L)	Toxicity Rating
Calcium chloride (35% solution)	14,857	12,440-17,742	6,387	5,273-7,763	Grade 0
Oil field brine	52,305	44,099-62,037	24,000	18,000-32,000	Grade 0
Road binder	4,337	3,877-4,851	1,342	1,000-1,800	Grade 1
Tembind	657	589-731	3,536	2,500-5,000	Grade 2
Dust bond (5:1)	535	469-609	62.5	55-71	Grade 2
DCS-225 (3:1)	191	166-218	521	415-727	Grade 2

Notes:

1. Based on aquatic toxicity rating system developed by IMCO/FAO/UNESCO/WHO, 1969. Grade ratings vary from 0-4, using the following ranges, and evaluated based or toxicity test results for rainbow trout:

- Grade 0 - >10,000 ppm
- Grade 1 - 1,000 - 10,000 ppm
- Grade 2 - 100 - 1,000 ppm
- Grade 3 - 1 - 100 ppm
- Grade 4 - <1 ppm

From Table 4.10, oil field brine is the least toxic dust suppressant to both rainbow trout and Daphnia magnia. Calcium chloride is lethal at approximately one quarter of the lethal oil field brine concentration, Road Binder and Tembind at approximately one sixteenth, and Dust Bond and DCS-225 at less than one hundredth of the concentration.

Toxicity tests for oils were carried out on aged solutions. Thus, the results indicate the toxicity of these compounds in oil which solubilize in water after 24 and 96 h. Using this method, lethal concentrations of bunker fuel, line wash oil and rerefined oil were found to exceed 10,000 mg/L (with 96 h aging).

Lethal concentrations of coke wash oil, after 96 h aging, were estimated to be approximately one fifth of the lethal concentration of oil field brine.

Table 4.11
Summary for Acute Toxicity Testing Results for Oil Dust Suppressants

Dust Suppressant	Aging Period[1]	Concentration (mg/L)	Mortality	
			Rainbow Trout (96 h)	Daphnia magnia (48 h)
Line wash oil[2]	24 h	10,000	non-lethal	non-lethal
	96 h	10,000	20%	20%
Coke wash oil[3]	24 h	10,000	50%	12%
	96 h	10,000	100%	6,474 mg/L (LC50)
	96 h	10,000	30%	-
	96 h	10,000		8,062 mg/L (LC50)
Bunker fuel[4]	24 h	10,000	non-lethal	non-lethal
	96 h	10,000	non-lethal	non-lethal
Rerefined oil[5]	24 h	10,000	non-lethal	25%
	96 h	10,000	30%	non-lethal

Notes:

1. Solution of oil and water aging period before testing.
2. Dark Journal Oil from Petro Canada.
3. Wash Oil A from Petro Canada.
4. Bunker fuel oil from Petro Canada.
5. Breslube rerefined oil from Safety-Kleen.

Sub-lethal effects were assessed for each of the traditional dust suppressants. Main findings are discussed in the following paragraphs.

Calcium present in brines has no relevant sub-lethal effects and may be beneficial to vegetation. Chloride negatively affects vegetation growth and germination, and produces an undesirable taste at high levels in drinking water.

All dust suppressants (except brines) have a significant biodegradable component. In addition, ammonia present in Tembind, and at a lower levels in oil field brine and Road Binder would contribute to biochemical oxygen demand (BOD), as would oil and grease. In surface water, this would result in oxygen depletion. Aquatic toxic effects as a result of BOD contamination from dust suppressants have not been reported, and should not be a problem if materials are not applied in the vicinity of surface waters.

Metals were present at low levels in most of the dust suppressants. A number of metals exceeded relevant guidelines for drinking water and aquatic life. However, only a few of these might be of human or environmental concern related to use of the various dust suppressants. Metals are not dermally penetrated, and therefore pose no handling concerns. It is important to note that the concentrations would be significantly diluted from application concentrations before reaching surface waters or groundwater

supplies. Furthermore, drinking water quality guidelines are based on lifetime consumption of 1.5 L per day and incorporate large safety factors. Thus, based on measured concentrations, metals would not likely contribute to human or aquatic toxic or sublethal effects resulting from dust suppressant use.

It should, however, be mentioned that metals are extremely persistent and some concern may arise over build-up through long-term use of dust suppressants, particularly those that require frequent application. Detailed exposure assessment and comparison to other sources necessary to evaluate these effects were not carried out within the scope of this study.

Total phenolics were measured in Domtar Road Binder at 14,000 µg/L. Phenolic compounds have been found to induce pathological changes in fish at concentrations of 20 to 70 µg/L, and tainting of fish at lower concentrations. However, studies have shown that little migration of phenols from the application site will occur. Therefore, aquatic toxicity should not be a concern if care is taken not to apply products in the vicinity of surface water.

Dioxin and furans present in Road Binder and Tembind at measured total TEQs less than 30 pg/L compared to an Interim Maximum Acceptable Concentration (IMAC) in drinking water of 15 pg/L and a guideline for soil assessment criteria of 1 µg TEQ/kg dry weight. Based on these guidelines, levels in Tembind or Road Binder do not pose significant toxic or sub-lethal concerns.

Many PAH compounds found at a range of concentrations in petroleum based and oil dust suppressants, with the exception of Dark Journal Oil have been shown to have teratogenic, mutagenic, and/or carcinogenic properties in animals and are probable human carcinogens. The highest levels of PAHs were found in bunker fuel; however, the heaviest compounds were found in Dust Bond and rerefined oil. The heavier PAHs (e.g. benzo (a) pyrene), which are the compounds of most concern are likely to remain closely associated with roadbed materials and not be very mobile. Therefore, contamination of drinking water or groundwater is unlikely. Ingestion and inhalation of road dust or oil mist during application may be a more likely route of exposure. There are many natural and anthropogenic sources of PAHs.

Volatile organic compounds, found in all petroleum based products at a range of levels, are known to be potentially toxic. Levels in coke wash oil and line wash oil were not significantly different from drinking water guidelines. The highest levels were in bunker fuel and rerefined oil. Benzene for example is a known human carcinogen. Ethylbenzene, toluene, and xylenes may also potentially cause adverse effects. However, given that most of these chemicals will be rapidly lost to the atmosphere via evaporation after application, and that the products are only used occasionally each season, it is perhaps more likely that VOCs would be of concern to applicators as opposed to bystanders or property owners. In the case of industrial site applications, on site worker exposure may be of concern.

4.5 ENVIRONMENTAL IMPACTS

Environmental impacts of traditional dust suppressants were assessed to determine the persistence and migration of the material and its components once it has been applied to land. In general, studies have not examined these impacts and therefore, they were based on the estimated behaviour of the contaminants in the dust suppressant.

Table 4.12 presents the components and various contaminants identified in each dust suppressant. Each of these contaminants is discussed below.

Calcium chloride present in brines moves through the environment with water, and therefore, will move deeper into the soil during wet periods, and return back to the surface on dry periods. During significant rainfall or where there are high drainage rates, calcium chloride will dissociate into constituent ions and will move freely with surface runoff or leachate.

Both Ca^{2+} and Cl^- ions are indefinitely persistent in the environment. Calcium will become adsorbed to soil particles and will not migrate extensively. Chloride will move with water. Literature on the effects of chloride applications to roads as a result of de-icing, indicates that increases are not significant. Chloride loadings applied to roads for dust suppression are three times less than for road de-icing.

Sodium, present in Domtar Road Binder and in brines is also indefinitely persistent. It is a very mobile ion, that will migrate with runoff and groundwater. Because the levels of sodium applied in dust suppressant applications are several order of magnitude less than for road de-icing, so are the relative impacts of dust suppressant applications.

Biochemical oxygen demand present in all of the dust suppressants except inorganic brines indicates that a portion of these materials will oxidize through bacterial activity. The rate of biodegradation will depend on several factors, and has not been established for the dust suppressants.

Oil and grease levels in these agents also contribute to BOD. Oil is primarily immiscible, and its migration will not be affected by water movement. Oil will migrate from the application site by leaching and penetrating into soil, and will be slowed by soil adsorption. Some components in oil will solubilize and be carried away in water, while others will volatilize. In soil, the Ontario MOE's guidelines for site clean-up recommend that oil and grease levels be less than 1 percent by weight.

In one study, ammonia and TKN concentrations were not increased in surface waters very near roads treated with Tembind, even after significant rainfall. This result indicates that ammonia, present in lower levels in oil field brine, Road Binder and Dust Bond, would also not affect surface waters near application sites. The properties of ammonia indicate that it will evaporate rapidly from the site, and remaining molecules be carried with runoff to soils and streams, where it will be biodegraded or used as nutrient, for vegetation.

Table 4.12
Dust Suppressant Components Assessed to Determine Environmental Impacts

Dust Suppressant	Calcium Chloride	Sodium	BOD	Oil & Grease	Lignin	Ammonia	Phenols	Metals	PAHs	VOCs	Dioxins
Calcium Chloride	•	•						•			
Oil Field Brine	•	•				•		•			
Tembind			•	•	•	•		•			•
Road Binder		•	•	•	•	•	•	•			•
DCS-225			•	•				•	•	•	
Dust Bond			•	•		•		•	•	•	
Dark Journal Oil			•	•				•		•	
Coke Wash Oil			•	•				•	•	•	
Bunker Fuel Oil			•	•				•	•	•	
Rerefined Oil			•	•				•	•	•	

Lignin and lignosulphonate present in pulping liquors are stable in the biosphere and very water soluble. They do not volatilize or leach appreciably through soil. Lignosulphonates in streams may cause discolouration and foaming and reduce biological activity.

Phenolics were measured in Road Binder at levels of 14,900 µg/L, although higher levels have been reported. One study showed that phenols would not persist for a long period in the environment, and that even in very wet weather, they will not migrate significantly from the application site. These studies indicate that bacterial activity and soil adsorption reduce the risk of environmental impacts associated with phenols in Road Binder.

Metals present in all dust suppressants were not at levels significant to the environment under normal dust suppressant application. In a study of the migration of metals from application sites in Ontario, levels of metals in road materials, ditch materials, and vegetation were measured. Samples were taken from sites treated with calcium chloride, oil field brine, waste oil, Tembind and Road Binder. Background metal levels did not increase significantly after application (Acres, 1988). The long term impacts of metals build-up after several applications has not been assessed.

Polynuclear aromatic hydrocarbons were detected in all petroleum based dust suppressants with the exception of line wash oil. Lighter molecules in this group, such as naphthalene and fluorene, will be subject to biodegradation, evaporation and leaching from the soil in passing water. Heavier molecules such as pyrene will remain at the soil site adsorbed to particles, and migration will be limited. Some biodegration will occur over the long term, and rates will be slowest for the heaviest, most persistent compounds.

Volatile organic compounds (VOC) were detected in all petroleum based products. Once the product has been applied to road surfaces, VOCs will volatilize rapidly and thus, will not persist at the application site.

Dioxins compounds, including octachlorodibenzodioxin and heptachlorodibenzodioxin were detected in samples of Tembind and Road Binder pulping liquors. The total dioxin concentrations, measured to be less than 0.03 ng TEQ/L compared to soil assessment criteria guidelines of 1,000 ng TEQ/kg dry weight. Concentrations in samples were roughly four orders of magnitude lower than guideline levels in soils.

Chapter 5
DISCUSSION ON THE USE OF PETROLEUM BASED PRODUCTS FOR DUST SUPPRESSION

One of the Ontario Ministry of the Environment's primary objectives in the study of traditional dust suppressants was to identify where in Ontario petroleum based agents were the only technically and cost effective solution for controlling dust.

The performance of oil and petroleum based products as dust suppressants under various conditions was evaluated through a literature search and telephone survey of users, and through field tests carried out as part of this study. Each of these study components are discussed in the following subsections.

5.1 LITERATURE SEARCH AND TELEPHONE SURVEY ON TECHNICAL EFFECTIVENESS

Limited specific literature exists on the technical effectiveness of virgin oil products and petroleum based products as dust suppressants. It is believed that all virgin oil products are equally effective as waste oils for dust suppression. Oil controls dust primarily by soaking into the surface, wetting and agglomerating the aggregate particles and preventing them from becoming airborne by the natural cohesive nature of the oil. Thus, literature on the technical effectiveness of used oil is applicable to virgin oil performance. Petroleum based products, which are oil/water or oil/water/asphalt emulsions, work on much the same principal.

The telephone survey of Ontario users carried out in this study found that, within Ontario, virgin oils are used widely within industrial yards using heavy equipment, and on unusual surfaces, such as in horse arenas that combine sand and woodchips, to control dust. The experience of these users indicates that oil is the only effective means of controlling dust when cost, effective lifetime, and level of dust control are considered. Petroleum based emulsions have been reported by users to be less effective than oils themselves.

As with all dust suppressants, the performance and effective lifetime are affected by weather, traffic load and surface composition.

The results of the telephone survey also indicated that rainfall did not reduce the dust suppressing abilities of virgin or used oils used on roads as noticeably as with other dust suppressants such as calcium chloride, lignosulphonates, etc. Users suggested that oil and petroleum based products resist leaching and runoff more than other types of suppressants. However, very rainy conditions do have a tendency to make surfaces treated with oil or other petroleum based products slippery, and may also promote potholing of municipal roads.

A Canada wide survey conducted by the British Columbia Ministry of the Environment (British Columbia, 1981) solicited mailed responses from various road agencies across Canada to find alternative dust suppressants to used oil. The results showed that oil was preferred in wet climates because longer periods of effective dust suppression resulted for oil treated roads compared to roads treated with other suppressants.

Traffic density and vehicle weights are variables in the effectiveness of oil in controlling dust emissions from roads and yards. The results of a survey of 15 Canadian and 2 U.S. highway agencies (Public Works Canada, 1983) showed that oil is the most popular road stabilizer and dust suppressant in areas with heavy truck traffic or high volume traffic. The telephone survey confirmed that industrial sites using heavy trucks, front end loaders, forklifts etc. also use virgin oil to suppress dust. No other dust suppressant is reported as effective for the same length of time as oils. However, the effectiveness of the oil is reduced when sharp turns and stops from trucks wear the surface. This action also promotes potholing.

The overall effectiveness of oils over other dust suppressants was shown in a study carried out for the Ontario Ministry of the Environment (Acres, 1988). This study compared the technical effectiveness of used oil and industrial oil against other dust suppressants used on municipal roads in Southern Ontario. No surface aggregate compositions or application rates were reported. Dust emitted from the treated road surface over a three month period was measured at various sites, where a number of dust suppressants had been applied. Results indicated that the oil applications provided the best dust control over all other dust suppressants tested. Dust measurements taken from a moving vehicle travelling over the treated surface also indicated that dust emissions from the oil treated surfaces were the lowest of all suppressants tested.

In general, Ontario users have found that oil is the only suppressant that provides an acceptable level of dust suppression in sandy soils or open gravel (i.e. gravel with very few fines), or in areas with little or no moisture in the surface. However, a report on road surface treatments in Alaska (State of Alaska, 1982) indicated that the presence of large amounts of fines, particularly clays, can promote the absorption of petroleum based palliatives into the surface particles, which would reduce the binding effects of the dust palliative and the natural cohesive nature of the fines. This would result in soft spots in the surface and eventual potholing.

Summary of Overall Effectiveness

The following points summarize the overall effectiveness of virgin oil as a dust suppressant relative to other conventional dust suppressants:

1. Oil products may resist leaching and runoff resulting from precipitation to a greater extent than other dust suppressants, such as brines and pulping liquors.

2. Oil has been shown to have a longer period of effectiveness in wet climates compared to other dust suppressants.

3. Oil is effective for longer periods of time over other dust suppressants in areas that have heavy weight or high volume traffic.

4. In studies, and based on user reports from Ontario, oil has been shown to provide the highest level of dust control over other dust suppressants under a range of conditions.

5. Oil has been reported to be an effective road treatment for sandy surfaces, and dry open gravel surfaces where other dust suppressants have not been cost effective (because too frequent applications are required).

6. Oil applications may promote potholing on road surfaces with high fines and/or clay content, where pulping liquors have been reported effective.

7. Petroleum based products have been reported to be less effective than oils.

5.2 FIELD EFFECTIVENESS TESTING OF OILS

5.2.1 Introduction

Field trials of dust control agents on unpaved roadways were carried out as part of CH2M Hill's evaluation of dust suppressants in Ontario.

The objective of the field study was to compare the effectiveness of virgin oils to calcium chloride on a road surface on which virgin oil has been exclusively used as a dust suppressant because it was found to be the only agent that was technically and cost effective for the site. Calcium chloride was selected for comparison because it is the most widely used dust suppressant in Ontario, and is a successful agent under a range of site conditions. However, as discussed in Chapter 4, calcium chloride has proven to require more frequent applications in sandy soil or open gravel, and under heavy traffic loading conditions.

5.2.2 Site Selection

Several sites were identified through the telephone survey where oil is applied for dust suppression. This list was narrowed down to a few potential sites for testing which met the following criteria:

- The surface composition was dry open gravel or sandy, where oil had been found by the user to be the most cost effective dust suppressant.

- There was adequate traffic volume to test the effectiveness of the dust suppressant over a 4 to 5 week period.

- The site authorities were willing to cooperate with the testing.

- Test equipment could be set up at the test site in accordance with accepted scientific protocol.

- The site was of acceptable configuration for testing. Ideally, an unpaved roadway for use in field trials should be reasonably straight for at least 600 m with a minimum width of approximately 8 m. These dimensions are based on the requirement that each test section (i.e. treated, untreated, treated) would be approximately 200 m long and that the two suppressants could be tested simultaneously. The minimum width (8 m) was required such that the total width of the roadway would be twice the maximum wheelbase of most large vehicles to ensure that curb effects would not be a modifier for the results during testing.

Based on the above criteria, a section of roadway on District Road 31 between Stanleydale and Ashworth in the Muskoka District Municipality, shown in Figure 5.1, was selected. The test section is typical of Northern Ontario roadways made up of sandy gravel/limestone material with 0 percent fines content (<75 μm), running nominally north-south.

The roadway test section has a slight crest at the centre with the virgin oil section at a lower elevation than the untreated section. The surrounding terrain shows a small upwind slope going west to east with coniferous trees approximately 10 m to the east and 5 m to the west.

The roadways in this district are typically graded and treated with virgin oils in early June. It was requested to the local official that 450 m of roadway not be treated with virgin oils for the field testing campaign.

5.2.3 Test Methodology

The roadway test section was subdivided into three 190 m nominal test sections, without intermediate transition areas, shown in Figure 5.2. The test sections were set up as follows, running north to south:

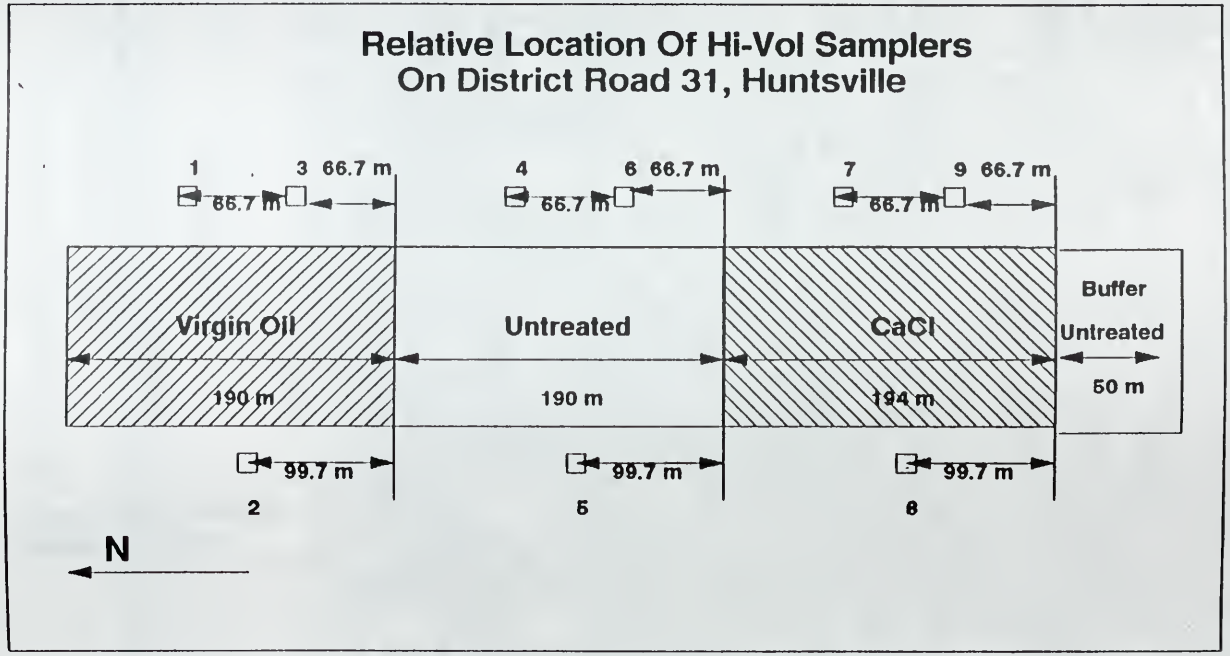
1. Virgin oil (Petro Canada Wash Oil A).

Figure 5.1

Dust Suppressant Field Trial Location

CONCORD

Figure 5.2



CONCORD

2. No treatment.
3. Calcium chloride (35 percent solution).

There was an untreated section (50 m) at the end of the calcium chloride section before the usual virgin oil treatment began again.

On-site field sampling and subsequent laboratory analysis of aggregate for moisture, density and particle sizing were based on adaptations of standard ASTM methods and carried out by BEAK Analytical Services (BAS) Ltd.

Ambient air sampling for total suspended particulate (TSP) matter was carried out by Concord Environmental with the aid of nine high volume (Hi-vol) samplers, shown in Figure 5.3, located approximately 1 m away at an elevation of 1 m on either side of the roadway. The Hi-vols were set up to sample at a flow rate of approximately 1.14 m^3/min onto glass fibre filters. The filters were conditioned and pre-weighed in the Concord laboratory as per standard protocol. All exposed filters were subsequently conditioned and re-weighed to determine the total accumulated mass.

The Hi-vols were calibrated prior to and after the field trials at the laboratory. The units are equipped with mass flow controllers and electronic elapsed timers. The flow measurement is obtained with the aid of a Dickson Mini-corder. The Dickson chart will record the start time, stop time and any power interruptions as well as flow rate such that the volume of air drawn across the filter can be determined. The total mass divided by the volume of air provides the dust concentration given in micrograms per cubic metre ($\mu g/m^3$) around the test sections.

As shown in Figure 5.2, two Hi-Vol samplers were located on the east side of the test section approximately one-third and two-thirds the length of a test section. On the west side, a single sampler was located midway along the length of each test section.

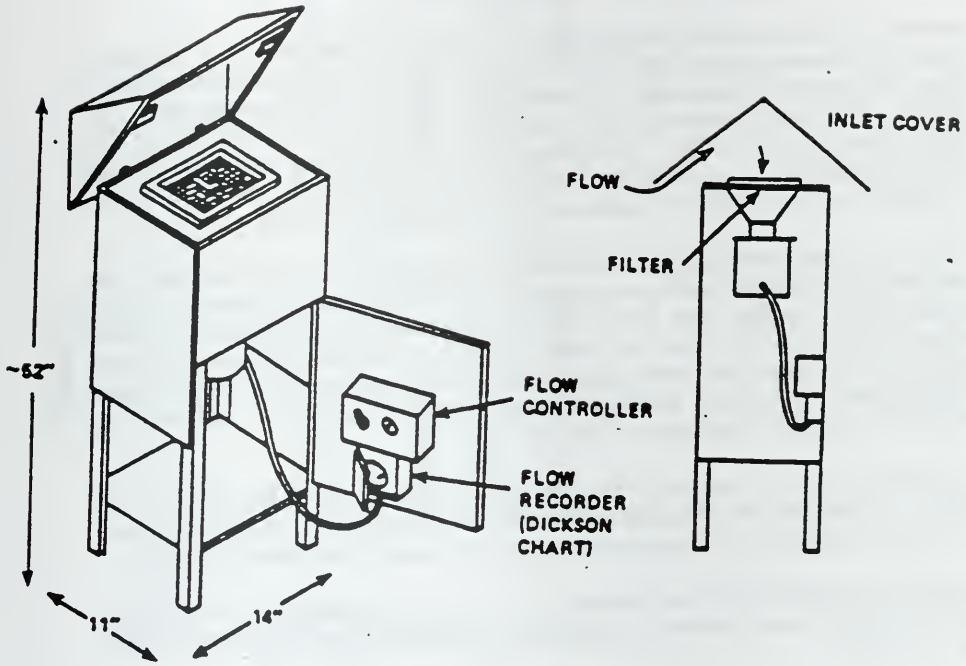
A mechanical traffic counter was installed in the centre of untreated section to determine the number of vehicles which travelled along the road during and between field trial campaigns.

5.2.4 Field Trial Schedule

Two two-day trial campaigns were scheduled to measure the effectiveness of the virgin oils and calcium chloride after application and after one month of wear. The initial field trial began the afternoon of the calcium chloride application and 1 day after the application of virgin oils on Tuesday, 11 June 1991. Surface samples were obtained prior to testing. The Hi-vols ran for 24 hours on Day 1 starting at 5:00 p.m. and 20 hours on Day 2 starting at 6:20 p.m. The number of vehicles which travelled over the test sections were recorded at the end of each test period.

Figure 5.3

High-Volume Sampler



The local township contact was advised not to grade the road section or re-apply the dust suppressant for the one month period. The field study team returned to the site on Wednesday, 10 July 1991 to complete the field program. The surface samples were obtained on this day by CH2M Hill personnel. Due to local thunder showers, testing began on 11 July when the surface became relatively dry. The same procedure which was used in the initial field trial was attempted for the follow-up visit. Unfortunately, the road was graded after the completion of the first day of sampling and due to an attempted theft of equipment, the second day of sampling was cut short.

5.2.5 Field Trial Results

Virgin oil and calcium chloride were both applied at 1.6 L/m^2 with the aid of a pressurize spray bar attached to a tanker. Virgin oil was applied by NorJohn Ltd. while the calcium chloride was applied by Chambers Road Oil Ltd. Both contractors are experienced, reputable agents.

Meteorological Conditions

The nearest Atmospheric Environment Service (AES) meteorological station is located at the Muskoka Airport which is 47.5 km southeast of the field trial. Historical winds for June shows that the winds are predominantly westerly and southerly with average speeds of 14.2 and 13.9 km/hr, respectively. Historical precipitation records show that the mean rainfall for the month of June is 82 mm.

Hourly meteorological data for the period 11 June to 13 July have been requested from the Canadian Climate Centre but data were unavailable from the AES computer system at the time of this report finalization in April 1992. As mentioned above, a significant amount of rainfall fell on July 10 prior to the commencement of the second field program.

Surface Sample Results

The moisture content and corresponding dry density measurements for the various test sections are summarized in Table 5.1. The follow-up of moisture and density samples were taken prior to the rain showers; thus, the surface moisture content is not representative of the surface during the Hi-vol sampling.

Table 5.1
Surface Aggregate Analysis

Visit	Treatment Section	Density (g/mL)	Moisture (%)	Gravel[1] (%)	Sand[1] (%)	Silt and Clay[1] (%)
Initial	Virgin oil	2.0	0.14	29.0	71.0	0.0
	Untreated	2.1	0.08	30.0	70.0	0.0
	Calcium chloride	2.3	0.65	32.5	67.5	0.0
Follow-up[2]	Virgin oil	1.7	1.30	48.0	52.0	0.0
	Untreated	2.3	0.09	43.0	57.0	0.0
	Calcium Chloride	2.6	1.05	50.0	50.0	0.0

Notes:

1.

Particle Type	Range (μm)
Clay	<2.0
Silt	2-50
Very fine sand	50-100
Fine sand	100-250
Medium sand	350-500
Coarse sand	500-1,000
Very coarse sand	1,000-2,000
Fine gravel	2,000-4,750
Coarse gravel	>4,750

2 Follow-up visit one month later. Samples taken before rainfall on July 10, 1991.

Figure 5.4 presents particle size distribution of the aggregate samples. Both initial and return samples show similar distributions between test sections. All samples show a lack of silt and clay (fines) for any test section. There is a general trend between all initial and follow-up samples. In all cases, there is a higher percentage of gravel and lower percentage of sand in the follow-up sample. This is expected since the smaller size fraction is more easily eroded. A significant amount of surface material was found on the side of the roadway. Both initial and follow-up distributions are log-normal and have bi-modal distributions[1].

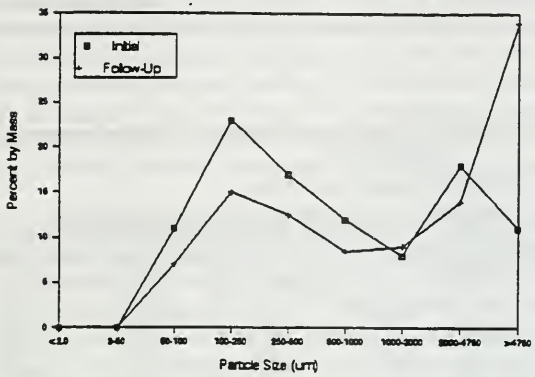
From Figure 5.4, the two populations are silt-sand (20 - 50 μm to 1,000 - 2,000 μm) and gravel (1,000 - 2,000 μm to >4,750 μm). For the initial visit, the modes are 100 - 250 μm and 2,000 - 4,000 μm for silt-sand and gravel respectively. For the follow-up visit, the silt-sand mode is the same as the initial visit while the gravel has shifted to >4,750 μm.

1 Mode is the value of the observation that occurs most frequently if the variable is discrete. The appearance of bimodal distribution means that the data contains values from two distributions. These are often encountered in particle size gradings.

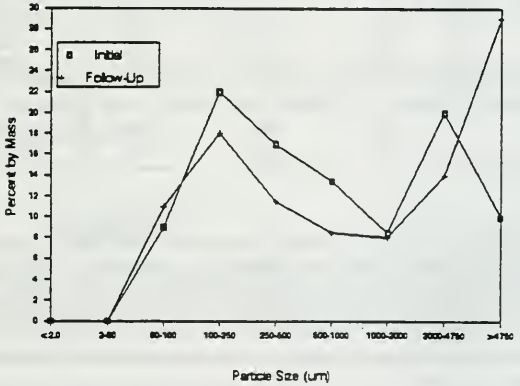
Figure 5.4

Particle Size Distribution of Test Sections

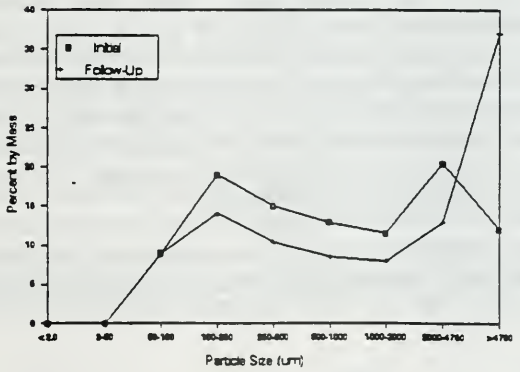
Particle Size Distribution of Virgin Oil Test Section



Particle Size Distribution of Untreated Test Section



Particle Size Distribution of CaCl Test Section



Particle Type	Range um
Clay	<2.0
Silt	2–50
Very Fine Sand	50–100
Fine Sand	100–250
Medium Sand	250–500
Coarse Sand	500–1000
Very Coarse Sand	1000–2000
Fine Gravel	2000–4750
Coarse Gravel	>4750

Hi-vol Sample Results

A summary of the total suspended particulate (TSP) concentrations and vehicle count data for the initial and return visits are presented in Table 5.2 with detailed data in Appendix B.

Table 5.2
Huntsville Road Dust Study
Hi-vol Dust Concentrations ($\mu g/m^3$) at Monitoring Locations

Location	Surface Treatment	11-12 June	12-13 June	11-12 July	12-13 July[1]
1	Oil	86.5	17.4	167.2	624.3
2	Oil	53.7	63.3	126.1	273.1
3	Oil	106.6	59.9	412.8	1,580.5
4	Untreated	258.6	495.3	227.6	2,246.6
5	Untreated	663.3	865.6	430.7	1,633.8
6	Untreated	447.7	743.2	276.1	3,492.9
7	CaCl	134.1	126.6	44.2	258.2
8	CaCl	65.9	93.9	29.4	161.6
9	CaCl	76.9	69.8	44.6	470.0
Vehicle Count					
• Period		119	86	154	102
• Total		119	205	3,270	3,372

Notes:

1. The July 12-13 Hi-vol dust concentration is invalid because the municipality graded the surface, and the sampling was aborted due to theft of the generators. The data are presented for interest only, and were not considered to be part of the analysis. The correct length of time was not recorded because the time of the generator theft is unknown.

For the first day of the initial visit, there is little difference between the oil treated section and the calcium chloride treated sub-sections. Highest dust concentrations occurred in the untreated section which are approximately 4 times greater than either of the treated areas. The vehicle count for this 24-hr period was 119. On the second day, there was a difference between the treated sections with lower concentrations (i.e. better performance) for the virgin oil section than for the calcium chloride section. It is interesting to note that the concentrations around the oil section were lower than the previous day while the other sections showed higher concentrations. The total traffic count over the entire section is 205 vehicles over 44 hours.

The total vehicle count up to the beginning of the follow-up visit was 3,116 vehicles, or approximately 104 vehicles per day. In addition, there was some rainfall on July 10,

1991. The first day (July 11) results of follow-up visit indicate that the calcium chloride is a significantly better dust suppressant than virgin oil. The calcium chloride TSP results are approximately 3 times lower than the oil and virtually an order of magnitude better than the untreated section. The vehicle count for this period was 154 vehicles giving a total of 3,270 vehicles that travelled over the road. As mentioned above, uncontrolled problems (i.e. road grading and attempted theft of equipment) affected the results of the second day of testing. It is interesting to note that even though the road was graded, the calcium chloride treated section generated lower dust concentrations than the oil treated section, which were lower than the untreated section.

It was observed that about 20 to 30 m of the oil treated section adjacent to the untreated section was covered with untreated gravel in the vicinity of the Hi-vol #3 sampler. This will likely explain the high dust levels at unit #3 as well as at the other virgin oil samplers. The carry over of road gravel to the oil section is likely caused by heavy northerly traffic as well as the oil section being on a downward slope of the roadway. The mechanical traffic count only provided total traffic counts and not as a function of direction. As sampling was carried out at the end of the week, it is likely that there was a high northerly flow of traffic due to cottagers which caused a high carry over of dust onto the oil section.

The poor performance of the virgin oil section can be attributed to the significant amount of carry over onto the virgin oil section, creating a source of potential suspendible material.

5.2.6 Conclusions

A comparison of the effectiveness of virgin oils and calcium chloride as dust suppressants were carried out with the aid of ambient air samplers to measure the quantity of suspended dust in the vicinity of roadways in Central Ontario. A roadway was divided into three sub-test sections (treated, untreated, treated) such that simultaneous testing could be carried out. Two field trial campaigns a month apart, were carried out to evaluate wear on the effectiveness of each suppressant.

Aggregate surface sample analysis from each test section shows that both initial and follow-up samples have bi-modal log-normal distributions. There were no fines found in any sample but the follow-up samples showed an increase in gravel size particles and a decrease in sand size particles. The loss of sand or smaller particles is expected since sand size particles can be more easily dislodged from a surface.

The Hi-vol results show that the virgin oils were initially a better dust suppressant than the calcium chloride. Both dust suppressants showed a significant improvement over the untreated section. After a month of meteorological and vehicle wear, the calcium chloride appeared to provide better performance. This was likely the result of a carry over of material from the untreated section onto the virgin oil section, generating a

large source of potential suspendible material which was captured by the air samplers. In addition, calcium chloride is a deliquescent agent, that performs best under humid conditions. The performance of the calcium chloride after a recent rainfall was superior to the oil. However, no information was available to indicate the overall performance of calcium chloride over oil in the range of conditions experienced over the test period.

5.3 COSTS

Table 4.1 summarizes the cost of traditional dust suppressants to Ontario users. Virgin oil products and rerefined oils are the highest priced dust suppressant materials, ranging in costs from $0.38 to $0.50 per litre, including application. The two petroleum based products ranged in applied costs of $0.17 to $0.19 per litre.

Typical seasonal costs to users of oils were reported to be $0.50 per square metre of treated area, and $0.61 to $1.03 per square metre for petroleum based products. These costs are higher than reported seasonal costs for other traditional dust suppressants, which ranged from $0.01 to $0.40 per square metre.

It is important to note that in spite of the relatively high seasonal costs for virgin oil applications, for certain areas, oils are considered to be the only technically effective dust suppressant.

Through a survey of oil users in Ontario, oil was identified as the most cost and technically effective dust suppressing agent:

- On surfaces with little fines content (<75 μm), such as sandy areas, open gravel, particularly where there is little surface moisture (e.g. high ground).

- On surfaces where there is heavy traffic weight and density, such as industrial haul roads and industrial yards, with truck traffic.

- In horse arenas, where surface materials are a combination of wood chips and sand.

Users of virgin oil products have tried using other petroleum based products, calcium chloride and pulping liquors, as well as used oil (before it was banned). In general, they prefer to use oil because it requires significantly fewer applications for the same effective period, and is therefore, less costly. An owner of a horse arena found in addition to its effectiveness, it did not dry out horses hooves, as would calcium chloride.

A review of costs indicate that in general users select oil products for dust suppression because they are effective at controlling dust for longer periods of time. For these

users, the number of applications is reduced compared to other traditional dust suppressants, and therefore oils are considered the most cost effective alternative.

5.4 ALTERNATIVES TO PETROLEUM BASED PRODUCTS

Users in Ontario of virgin oils were adamant that virgin oils were necessary for controlling dust to safe levels on roads and surfaces in certain situations. If the Ministry of the Environment were to consider legislating control over oil applications, based on their environmental impacts, the following alternatives could be considered.

1. Controls on the levels of contaminants in oils used for road dust suppression. From the results of this study, the range and concentrations of contaminants in the four oil products and two petroleum based products vary extensively, depending on the raw materials and manufacturing process. Thus, the range of their impacts on the environment as a result of applications would also vary. More detailed study of the relative impacts of each product would provide information to allow selection of a maximum limit for concentrations of target contaminants in dust suppressants, or a definition of those products designated for use on Ontario roads and surfaces.

2. Alternative dust suppressant products that would be effective in situations where only oil is currently used could be offered on the market as a replacement to oil.

   Two alternative dust suppressants have been identified, although more products are becoming available on the market. The two products are Soil Sement, a polymer base emulsion, and Perma Zyme, an enzyme/sugar surfactant. The environment impacts, costs and effectiveness of these would need to be evaluated against those of petroleum based products if these were to be offered as alternatives to current oil users.

3. A very costly approach would be to permanently seal roads by paving them at estimated costs of $10.00 per square metre, to reduce dust to environmentally acceptable levels on an on-going basis.

Chapter 6
SUMMARY OF FINDINGS

Main findings in the study of dust suppressants used in Ontario are summarized below:

General

1. Ten traditional dust suppressants were available for use in Ontario at the time of the ban on waste oils, including two calcium chloride brines, two pulping liquors, two petroleum based emulsions, three virgin oils and rerefined oil.

2. Calcium chloride is the most widely used dust suppressant in Ontario. Bunker fuel oil and rerefined oil are not currently used as dust suppressants.

3. Very few studies have examined the environmental impacts of applying road dust suppressants, or the toxic or sub-lethal effects of dust suppressant materials.

Effectiveness and Cost

1. Brines in general are most effective on roads with a good mix of fine and porous materials and in humid conditions. Pulping liquors perform optimally where road materials have a high percentage of fines, and in very dry weather. Oils and petroleum based products perform well when the road materials have both fines and sand, but also where the road materials are porous (i.e. no fines). Oils are reported to be more effective than petroleum based products in controlling dust.

2. Road Binder is the least expensive road dust suppressant at \$0.01 to \$0.02/m^2 per season. Road treatment with brines, Tembind and oils typically range in cost from \$0.10 to \$0.50/m^2 per season. Petroleum resin products are most expensive. Costs vary depending on frequency of application required, based on traffic load, surface materials and climate.

Chemical Composition and Effects

1. Brines contain persistent salts, including sodium and chloride, which migrate readily from the application site with water. Chloride has the potential to affect growth and germination of vegetation, and both sodium and chloride can build-up in surface waters. Significant impacts resulting from dust suppressant applications have not been reported.

2. All dust suppressants except brines consist of a large biodegradable component, which has the potential to reduce dissolved oxygen concentrations in surface waters. However, these impacts should not be a concern if care is taken not to apply dust suppressants in the vicinity of surface water.

3. Various metals were detected in all materials, at a range of levels, with the highest levels in bunker fuel. Studies indicate that metals in all traditional dust suppressants, were not at levels that would contribute to human or environmental toxic effects or have impacts on the environment under recommended application. Long-term build-up of metals after frequent application has not been established.

4. Volatile organic compounds (VOC) present in all petroleum based products will not persist at the application site, as they will evaporate. However, these compounds have some adverse toxic and sub-lethal effects. Exposure may occur through inhalation of mist during application, or fumes for a short-time after application.

5. Polynuclear aromatic hydrocarbon (PAH) compounds present in all of these petroleum based products, except line wash oil, may have carcinogenic, teratogenic and/or mutagenic properties. Heavier compounds which are those of most concern, will persist at the application site. Routes of exposure may include inhalation of mist during application or inhalation of road dust.

6. Phenolics compounds are present in Road Binder. Because these compounds have been shown to migrate little from the application site and degrade rapidly, environmental impacts and toxic effects are not likely to result if application in the vicinity of surface waters is avoided.

Acute Toxicity

1. Oil field brine is the least toxic non-petroleum based dust suppressant to rainbow trout and Daphnia magna, followed by calcium chloride and the two pulping liquors. The petroleum based emulsions were the most toxic. The toxicity of oils was measured only on those product components which dissolved in water and direct comparison to results for the remaining products is not possible. Of the oils tested, coke wash oil was the most toxic. Lethal dosages of bunker fuel and rerefined oil exceeded 10,000 mg/L.

Examination of Petroleum Based Dust Suppressants

1. In Ontario, there are specific circumstances where oils are believed by users to be the only cost effective dust suppressant. These are where road materials have little or no fines content and dry conditions, where there is heavy and/or high volume traffic, and other unusual circumstances (i.e. horse arenas).

2. In a road test carried out for this study, oil controlled dust to a greater extent than calcium chloride on a surface with porous materials (i.e. no fines) immediately after application. The calcium chloride treated section emitted less dust 4 weeks later, in a 2 day period after a heavy rainfall, although the oil section also performed adequately.

3. Only two alternatives to those covered in the group of traditional dust suppressants were identified that could potentially control dust on surfaces currently using oil. Environmental impacts and effectiveness in these circumstances have not been defined.

4. Environmental impacts of using virgin oil for road dust suppression could be controlled by:

    - Setting limits on contaminants in oils to be applied to roads.
    - Identifying alternatives to oil that would be as cost and technically effective.
    - Paving roads, where available dust suppressants will not perform effectively.

APPENDIX A

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Aldrid, Sid	Stelco Steel	Line Wash Oil	(416) 528-2365
Antonio, Philip	Town of Milton	Coke Wash Oil	(416) 878-7211
Armstrong, Jack	MTO Research Branch	Road Binder	(416) 235-5254
Baker, Dick	Dust Allayers Inc.	Dust Bond	(419) 525-4988
Bandy, David	Esso/Imperial Oil	Several Oil Products	(416) 733-5344
Barry, Dave	Town of Huntsville	Calcium Chloride Tembind	(705) 789-2391
Bell, Don	Town of Barrie	Calcium Chloride	(705) 726-4242
Belling, Peter	MOE Spills Action Centre		1-800-268-6060
Benson, Bob	Temfibre Inc.	Tembind	(705) 495-2195
Bertin, Jim	Petro Canada Inc.	Several Oil Products	(416) 827-4678
Billings, Vince	Glenmorgan	Past Waste Oil User	(705) 447-2410
Bondy, Jim	Esso/Imperial Oil	Several Oil Products	(519) 641-3270
Bowman, Brent	NorJohn Ltd.	Several Products	(416) 336-1216
Bratley, Dave	NorJohn Ltd.	Several Products	(416) 336-1216
Britton, Colin	Shell Canada Ltd.	Several Oil Products	(416) 827-1141
Brook, Peter	Ministry of Natural Resources Forest Access Roads	Calcium Chloride	(416) 965-2741
Brown, Tom	Township of Lake of Bays	DCS	(705) 635-2851
Bullock, Neil	Bayshore Veggie Shipping	Coke Wash Oil	(416) 335-3523
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Campney, Bob	Domtar Packaging Ltd.	Road Binder	(613) 392-6505
Carmicheal, Paul	Miller Paving	Calcium Chloride	(416) 475-6660
Chambers, Mildred	Chambers Road Oil	Several Products	(705) 687-2629
Christie, Eric	Brighton Township	Road Binder	(613) 475-1840
Ciruna, John	Esso/Imperial Oil	Several Oil Products	(416) 968-5014
Cloutier, Gilles	Environment Canada, Environment Emergency Branch		(819) 997-3352
Cochrane, Robert	Ontario Petroleum Inst.	Oil Field Brine	(519) 472-1542
Cocumi, John	H.S. Batram Ltd. (lumber yard)	Dust Bond Coke Wash Oil	(416) 662-8931
Cooke, Sid	Town of Forest	Oilfield Brine	(519) 786-2843

Telephone Contact References

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Demeo, John	Canadian Salt (Windsor Salt)	Calcium Chloride	(416) 822-0321
Didtrek, Donna	Da Lee Dust Control	Several Products	(416) 643-1135
Dwyer, Leo	Stelco Steel	Line Wash Oil	(416) 528- 2365
Ellerker, Larry	MTO Air Resources Branch		(416) 235-4046
Engelhardt, Kurt	Hoechst Canada	Hoe S 2745	(514) 333- 3630
Ferguson, John	Township of Orillia	Calcium Chloride	(705) 325-2316
Frye, Kathie	South West Sales Corp.	Oilfield Brine Calcium Chloride	(519) 892-3508
Gaston, Brian	Ministry of Transport		(416) 235-3664
Glas, Reg	Township of Burford	Calcium Chloride	(519) 449-2491
Gombola, Gordy	MTO-Regional Highways	Calcium Chloride	(807) 473-2067
Grant, Bruce	Stratford Landfill	Calcium Chloride Steel Slag	(519) 273-5041
Hansen, Kathy	MOE Waste Management Branch		(416) 323-5194
Janjevich, Jim	Petro Canada Inc.	Several Oil Products	(416) 730-2946
Jeffrey, Rob	Edward Fuels	Various Products	(519) 524-8386
Jewer, Fred	MTO Field Operation		(416) 235-3668
Johnson, Lyle	Stelco Steel	Line Wash Oil	(416) 528- 2365
Kennedy, Ron	Ministry of Health and Safety Branch, Surface Mines	Water	(519) 681-1784
Klenk, Bill	Turtle Lake Exploration	Salt Brine	(705) 671-3789
Labelle, Charles	MTO Purchasing Dept.		(416) 235-3761
Lallo, Priya	Nalco	Dust Ban	(416) 632-8791
Lavendar, Bob	Sandbanks Provincial Parks	Calcium Chloride	(613) 393-3319
Lehman, John	Township of Yarmouth	Calcium Chloride DCS-225	(519) 631-4860
Lucas, Howard	St. Clair Parkway	Oilfield Brine	(519) 862-2201
Magder, Marilee	Burnstein Brick	Line Wash Oil	(416) 937-2050
Major, Bill	Temfibre Inc.	Tembind A-002	(819) 627-9505
Mattè, Claude	Shell Canada Ltd.	Several Oil Products	(416) 443-7111
McCallum, Jim	Temfibre Inc.	Tembind A-002	(819) 627-9505
McDonald, Mr.	Hollowell Township	Road Binder	(613) 393-2011
Mckee, Jim	Domtar Packaging Ltd.	Road Binder	(613) 392-6505

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Name	Affiliation	Product Used/Sold	Telephone #
McKercher, Clark	Thunder Bay	Calcium Chloride	(807) 473-2014
McLeod, Rod	Ministry of Natural Resources Forest Access Roads	Calcium Chloride	(705) 675-4120
McNaughton, Kirt	Shell Canada Ltd.	Several Oil Products	(416) 443-7099
Moore, Glen	Petro Canada Inc.	Several Oil Products	(416) 730-2000
Moran, Brian	Murray Township	Road Binder	(613) 392-4733
O'Connor, Ed	Provamar Fuels	Various Oil Fuels	(416) 549-9402
O'Connor, Tom	Burlington Terminals	None	(416) 578-0686
Oree, Ruston	Sifto Salt	Calcium Chloride	(416) 624-7638
Overbaugh, David	Township of Norfolk	Coke Wash Oil	(519) 875-4409
Page, Merv	Huntsville Township	Coke Wash Oil	(705) 789-2742
Palenen, Pente	Petroleum Affairs Office	Oil Field Brine	(519) 661-2711
Parker, Chuck	Town of Orillia	Calcium Chloride	(705) 325-1311
Pierre, Joe	Town of Gravenhurst	Calcium Chloride	(705) 687-3412
Pierson, Doug	NorJohn Ltd.	Several Products	(416) 356-7222
Poncelet, Karen	Sifto Salt	Calcium Chloride	(416) 629-7083
Pritchard, Erny	MTO-Secondary Highways	Calcium Chloride	(416)235-3550
Roberts, Bill	Sherman Sand and Gravel	Coke Wash Oil	(416) 844-1441
Roote, Daniel	Saugeen Indian Reserve	Dust Bond	(519) 797-3934
Sage, Don	Haldiman Township	Road Binder	(416) 349-2700
Schofield, Dale	Safety Kleen Ltd. Breslube Division	Rerefined Oil	(519) 648-2291
Schwartzel, Charles	Esso/Imperial Oil	Several Oil Products	(416) 498-2470
Silver, Robert	Chemlink	Dust Block	(215) 524-1802
Speck, Ron	Algonquin Park	Calcium Chloride	(613) 637-2780
Stazyna, John	Global Enzymes (Ontario) Inc.	Perm zyme	(416) 793-9035
Thompson, Keith	Keith Thompson Ltd.	Several Products	(705) 522-2900
Troup, Len	Port Carling (Township of Muskoka)	DCS Tembind	(705) 765-3156
Van Veer, Bob	Sault Ste. Marie	Tembind	(705) 945-6830
Vetor, Kirk	E.B. Eddy Forrest Products	Tall oil	(705) 869-2020
Vitale, Robert	Midwest Industrial Supply Inc.	Soil Sement	(216) 456-3121
Vulcovik, Andy	Shell Canada Ltd.	Several Oil Products	(416) 827-1141
Walters, Ted	Haldiman Township	Tembind	(416) 772-3324

Telephone Contact References			
Name	Affiliation	Product Used/Sold	Telephone #
White, Cliff	Coburg Township	Road Binder	(613) 342-2418

APPENDIX B

Field Trial Data

1. Hi-Vol Results.
2. Surface Sample Analysis

HUNTSVILLE ROAD DUST COLLECTION DATA SHEET
INITIAL VISIT: 11/06/91 UNTIL 13/06/91

DATE / TIME / V. COUNT	HI-VOL NUMBER	FILTER NUMBER	CORRECTED FLOWRATE (S ft3/MIN)	SAMPLE DURATION (MIN)	VOLUME SAMPLED (ft3)	PARTICULATE WEIGHT (mg)	TSP CONC. (µg/ft3)	TSP CONC. (µg/m3)	ROAD SURFAC TREATMENT
JUN 11 TO	1	H009	42.56	1320	56179.65	137.67	2.45	86.53	OIL
JUN 12	2	H008	33.65	1440	48450.00	73.73	1.52	53.73	OIL
	3	H007	43.31	1320	57171.62	172.53	3.02	106.56	OIL
1700HRS-	4	H006	43.31	1440	62369.04	456.78	7.32	258.61	UNTREATED
1700HRS	5	H005	40.22	1440	57916.63	1087.98	18.79	663.32	UNTREATED
	6	H004	31.66	1440	45585.62	577.92	12.68	447.66	UNTREATED
VEHICLE	7	H003	45.49	1440	65506.25	248.77	3.80	134.10	CaCl
COUNT=119	8	H002	46.19	1440	66518.50	124.16	1.87	65.91	CaCl
	9	H001	42.18	1440	60738.44	132.19	2.18	76.85	CaCl
JUN 12 TO	1	H019	45.51	1200	54614.50	26.86	0.49	17.37	OIL
JUN 13	2	H018	48.18	1200	57817.42	103.56	1.79	63.25	OIL
	3	H017	48.50	1200	58205.18	98.78	1.70	59.93	OIL
1820HRS-	4	H016	45.17	1200	54200.57	760.22	14.03	495.27	UNTREATED
1420HRS	5	H015	40.80	1200	48955.53	1200.09	24.51	865.60	UNTREATED
	6	H014	33.15	1200	39779.49	837.25	21.05	743.19	UNTREATED
VEHICLE	7	H013	45.51	1200	54614.50	195.75	3.58	126.56	CaCl
COUNT=86	8	H012	48.50	1200	58205.18	154.74	2.66	93.87	CaCl
	9	H011	43.40	1200	52080.65	103.01	1.98	69.84	CaCl

CONCORD ENVIRONMENTAL

HUNTSVILLE ROAD DUST COLLECTION DATA SHEET
FOLLOW-UP VISIT: 11/07/91 UNTIL 13/07/91

DATE / TIME / V. COUNT	HI-VOL NUMBER	FILTER NUMBER	CORRECTED FLOWRATE (S ft3/MIN)	SAMPLE DURATION (MIN)	VOLUME SAMPLED (ft3)	PARTICULATE WEIGHT (mg)	TSP CONC. (µg/ft3)	TSP CONC. (µg/m3)	ROAD SURFAC TREATMENT
JUL 11 TO	1	H030	41.38	1440	59582.59	282.14	4.74	167.21	OIL
JUL 12	2	H031	43.20	1440	62202.71	222.05	3.57	126.05	OIL
	3	H032	37.17	1440	53531.45	625.84	11.69	412.82	OIL
1115HRS-	4	H033	42.39	1440	61037.86	393.49	6.45	227.64	UNTREATED
1115HRS	5	H034	48.16	1440	69347.44	845.87	12.20	430.71	UNTREATED
	6	H035	45.83	1440	65994.65	515.98	7.82	276.08	UNTREATED
VEHICLE	7	H036	45.45	1440	65449.27	81.97	1.25	44.22	CaCl
COUNT=154	8	H037	46.38	1440	66794.29	55.69	0.83	29.44	CaCl
	9	H038	47.34	1440	68170.68	86.06	1.26	44.58	CaCl
JULY 12	1	H021	46.89	595	27898.28	493.25	17.68	624.30	OIL
	2	H022	43.59	630	27464.55	212.44	7.74	273.13	OIL
1300HRS-	3	H023	37.61	595	22380.67	1001.75	44.76	1580.49	OIL
2200HRS*	4	H024	45.43	630	28620.18	1820.91	63.62	2246.59	UNTREATED
	5	H025	50.48	540	27256.95	1261.14	46.27	1633.78	UNTREATED
VEHICLE	6	H026	46.00	630	28977.23	2866.43	98.92	3492.94	UNTREATED
COUNT=102	7	H027	47.61	630	29996.76	219.32	7.31	258.17	CaCl
	8	H028	48.78	630	30732.56	140.66	4.58	161.61	CaCl
	9	H029	46.42	630	29242.10	389.23	13.31	470.01	CaCl

*-- Attempted theft of equipment discovered in progress at 2315 HRS. Perpetrators flee scene with one generator in their posession. One generator discovered to have been turned off(supplied HV 5). Since the engine was cold, we estimate that it was disengaged at approximately 2200 HRS.

-- The section of road used in this study was graded by township personel at 1200 HRS on July 12 just prior to the commencement of the second half of the final 24 HR sample period.

CONCORD ENVIRONMENTAL

BAS Laboratories Limited
Consulting Environmental Chemists

14 Abacus Road
Brampton, Ontario
Canada L6T 5B7
Phone (416) 458-4505
Fax (416) 458-7303

Report of analysis

REPORT
07/19/91 11:45:08

Received: 06/20/91

Work Order # 91-06-175

REPORT TO: CH2M Hill Engineering Ltd.
Suite 100, Plaza 3
2000 Argentina Road
Miss., Ont., L5N 1V9
ATTEN: Tacoma Zach

PREPARED BY: BAS Laboratories Limited
14 Abacus Road
Brampton, Ontario
L6T 5B7
ATTEN: Chester Lastoria
PHONE: 416-458-4505

CERTIFIED BY

CONTACT: K MCMILLAN

CLIENT: CH2M HILL
SAMPLES: 4
COMPANY: CH2M Hill Engineering Ltd.
FACILITY: Mississauga, Ontario

BAS Laboratories Limited hereby disclaims any and all liability related to anomalous data arising from normal analytical and or sampling protocol. Should further information be required, please contact the Manager.

WORK ID: ONT29451.AO
TAKEN: 06/10/91 - 06/11/91
TRANS:
TYPE: Solid
P.O. #: TOR00215
INVOICE: under separate cover

SAMPLE IDENTIFICATION

01 #1 CaCl2 Section
02 #2 Oiled Section
03 #3 Control Section

TEST CODES and NAMES used on this report

DENSIT	Density
FAST	FAST
MOIST	Moisture
PIPETT	PIPETTE

ACCUTEST LABS PARTICLE SIZE DETERMINATION

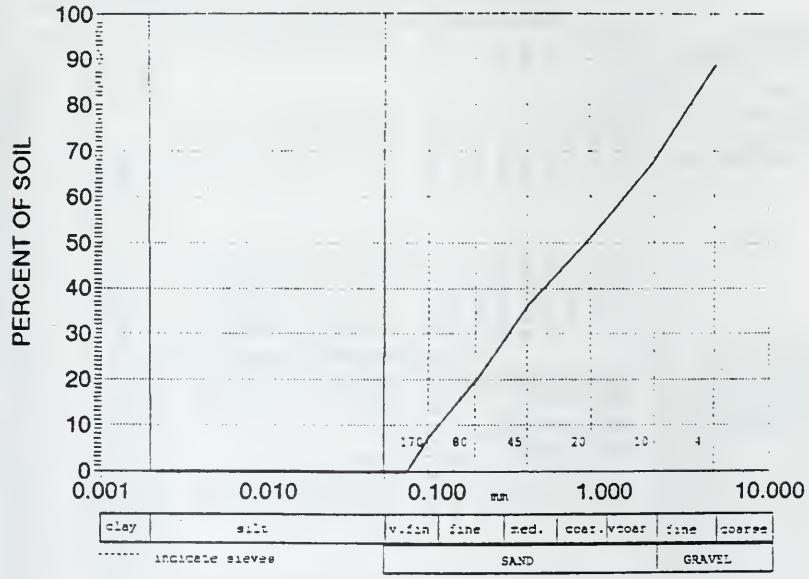
SAMPLE NUMBER: A1-1292-1 SAMPLE NAME: 06-175-01

DATE JULY 8,1991

MOISTURE 0.0 PERCENT

ORGANIC MATTER _____ PERCENT

PARTICLE SIZE



PARTICLE TYPE	PERCENT OF SAMPLE
COARSE GRAVEL	12.0
FINE GRAVEL	20.5
VERY COARSE SAND	11.5
COARSE SAND	13.0
MEDIUM SAND	15.0
FINE SAND	19.0
VERY FINE SAND	} 9.0
SILT	
CLAY	

COMMENTS:

Sample was small stones and pebbles mixed with sand.

ANALYST: [signature]

ACCUTEST LABS PARTICLE SIZE DETERMINATION

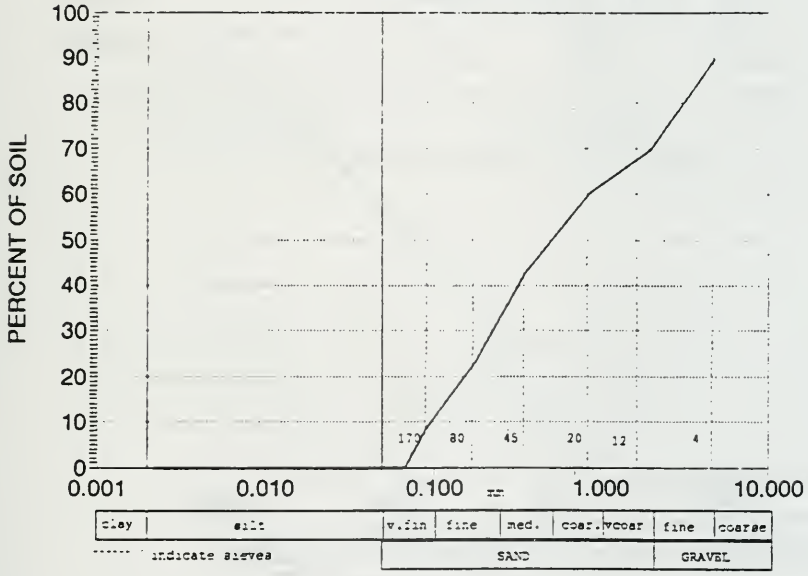
SAMPLE NUMBER: A1-1292-2 SAMPLE NAME: 06-175-02

DATE JULY 8,1991

MOISTURE 0.0 PERCENT

ORGANIC MATTER _____ PERCENT

PARTICLE SIZE



PARTICLE TYPE	PERCENT OF SAMPLE
COARSE GRAVEL	11.0
FINE GRAVEL	15.0
VERY COARSE SAND	5.0
COARSE SAND	12.0
MEDIUM SAND	17.0
FINE SAND	23.0
VERY FINE SAND	} 11.0
SILT	
CLAY	

COMMENTS:

Sample was small stones and pebbles mixed with sand.

ANALYST: Tullio Cruz

ACCUTEST LABS PARTICLE SIZE DETERMINATION

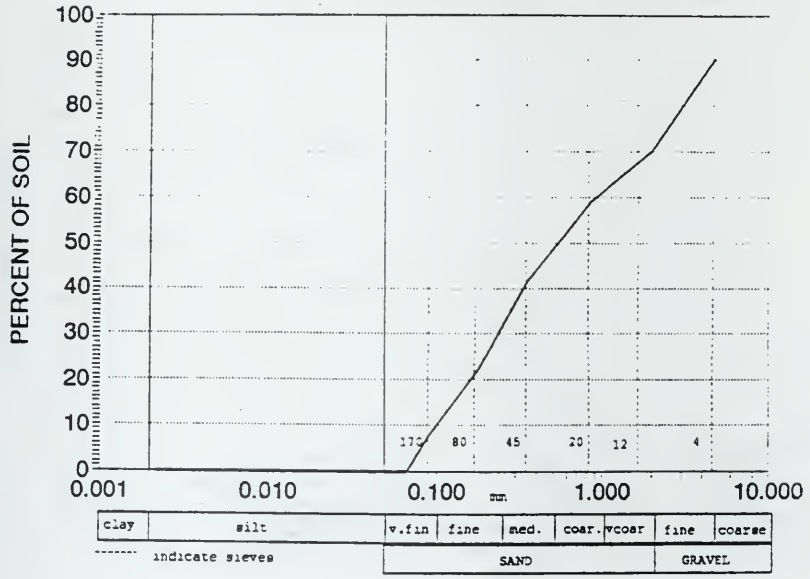
SAMPLE NUMBER: A1-1292-3 SAMPLE NAME: 06-175-03

DATE JULY 8,1991

MOISTURE 0.0 PERCENT

ORGANIC MATTER _____ PERCENT

PARTICLE SIZE



PARTICLE TYPE	PERCENT OF SAMPLE
COARSE GRAVEL	10.0
FINE GRAVEL	30.0
VERY COARSE SAND	8.5
COARSE SAND	13.5
MEDIUM SAND	17.0
FINE SAND	22.0
VERY FINE SAND	
SILT	9.0
CLAY	

COMMENTS:

Sample was small stones and pebbles mixed with sand.

ANALYST: Cindi Lacy

BAS Laboratories Limited
Consulting Environmental Chemists

14 Abacus Road
Brampton, Ontario
Canada L6T 5B7

Phone (416) 458-4505
Fax (416) 458-7303

Report of analysis

REPORT: CH2M Hill Engineering Ltd.
TO: Suite 100, Plaza 3
2000 Argentina Road
Miss., Ont., L5N 1V9
ATTEN: Tacoma Zach

WORK ID: ONT29451.AO
P.O. #: TOR00215
LABORATORY WORK ORDER #: 91-06-175
RECEIVED: 06/20/91 CLIENT: CH2M_HILL
REPORTED: 07/19/91 NUMBER OF SAMPLES: 4

Test	Units	#1 CaCl2 Section	#2 Oiled Section	#3 Control Section
Density	gram/mL	2.3	2.0	2.1
FAST		See Attached	See Attached	See Attached
Moisture	%	0.65	0.14	0.08
PIPETTE		See Attached	See Attached	See Attached

Analysis Certified By:

Recycled Paper

BAS Laboratories Limited
Consulting Environmental Chemists

14 Abacus Road
Brampton, Ontario
Canada L6T 5B7

Phone (416) 458-4505
Fax (416) 458-7303

Report of analysis

REPORT

Work Order # 91-06-175

Received: 06/20/91

Test Methodology

TEST CODE FAST NAME FAST

Emery settling tube

Reference: Rukavina N.A., and G.A. Duncan.1970. F.A.S.T. - Fast analysis of sediment texture. Proc. 13th Conf. Great Lakes Res. 274-281.

TEST CODE MOIST NAME Moisture

Gravimetric - 105 dried

Reference: Standard Methods for the Examination of Water and Wastewater, 16th ed. No. 209 F.

TEST CODE PIPETT NAME PIPETTE

Short settling tube

Reference: Rukavina, N.A., and G.A. Duncan. 1970. F.A.S.T. - Fast analysis of sediment texture. Proc. 13th Conf. Great Lakes Res. 274-281.

BAS Laboratories Limited
Consulting Environmental Chemists

14 Abacus Road
Brampton, Ontario
Canada L6T 5B7
Phone (416) 458-4505
Fax (416) 458-7303

Report of analysis

REPORT 13

Page 1 | Work Order # 91-07-152

Received: 07/17/91 | 08/06/91 09:54:11

REPORT TO
CH2M Hill Engineering Ltd.
Suite 100, Plaza 3
2000 Argentina Road
Miss., Ont., L5N 1V9
ATTEN Tacoma Zach

PREPARED BY
BAS Laboratories Limited
14 Abacus Road
Brampton, Ontario
L6T 5B7
ATTEN Chester Lastoria
PHONE 416-458-4505

CERTIFIED BY

CONTACT K MCMILLAN

CLIENT CH2M HILL SAMPLES 4
COMPANY CH2M Hill Engineering Ltd.
FACILITY Mississauga, Ontario

BAS Laboratories Limited hereby disclaims any and all liability related to anomalous data arising from normal analytical and or sampling protocol. Should further information be required, please contact the Manager.

WORK ID Soil Monitoring
TAKEN 07/10/91
TRANS
TYPE Soil
P.O. # TOR00215
INVOICE under separate cover

SAMPLE IDENTIFICATION		TEST CODES and NAMES used on this report	
01	4	DENSIT	Density
02	5	MOIST	Moisture
03	6	PARTIC	Particle Size

BAS Laboratories Limited
Consulting Environmental Chemists

14 Abacus Road
Brampton, Ontario
Canada L6T 5B7
Phone (416) 458-4505
Fax (416) 458-7303

Report of analysis

REPORT: CH2M Hill Engineering Ltd.
TO: Suite 100, Plaza 3
2000 Argentina Road
Miss., Ont., L5N 1V9
ATTEN: Tacoma Zach

WORK ID: Soil Monitoring
P.O. #: TOR00215
LABORATORY WORK ORDER #: 91-07-152
RECEIVED: 07/17/91 CLIENT: CH2M_HILL
REPORTED: 08/06/91 NUMBER OF SAMPLES: 4

Test	Units	4	5	6
Density	gram/mL	1.73	2.3	2.6
Moisture	%	1.31	0.09	1.05
Particle Size		See Attached	See Attached	See Attached

Analysis Certified By: K Mill

Recycled Paper

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Laboratories
Limited
Consulting
Environmental
Chemists

Report of analysis

14 Abacus Road
Brampton, Ontario
Canada L6T 5B7
Phone (416) 458-4505
Fax (416) 458-7303

REPORT

Work Order # 91-07-152

Received: 07/17/91

Test Methodology

TEST CODE MOIST NAME Moisture

Gravimetric - 105 dried
Reference: Standard Methods for the Examination of Water and Wastewater, 16th ed. No. 209 F.

TEST CODE PARTIC NAME Particle Size

t available.

Recycled Paper

BAS Laboratories Limited
Consulting Environmental Chemists

14 Abacus Road
Brampton, Ontario
Canada L6T 5B7

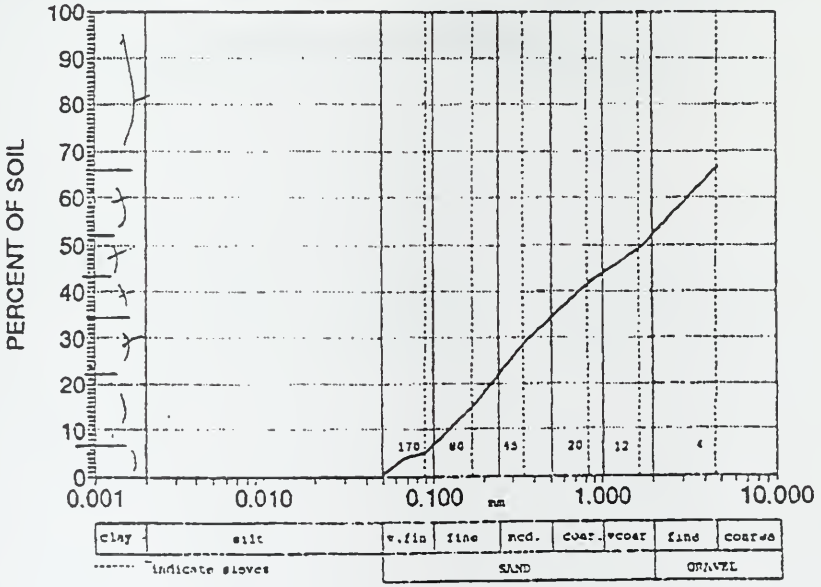
Phone (416) 458-4505
Fax (416) 458-7303

Report of analysis

SAMPLE NUMBER: A1-1486-1 SAMPLE NAME: 07-152-1

DATE	July 26,1991	
MOISTURE	0.8	PERCENT
ORGANIC MATTER		PERCENT

PARTICLE SIZE



PARTICLE TYPE	SIZE mm	% Damp
COARSE GRAVEL	>4.750	34.0
FINE GRAVEL	>2.000-4.750	14.0
VERY COARSE SAND	>1.000-2.000	9.0
COARSE SAND	>0.500-1.000	8.5
MEDIUM SAND	>0.250-0.500	12.5
FINE SAND	>0.100-0.250	15.0
VERY FINE SAND	>0.050-0.100	7.0
SILT	>0.002-0.050	
CLAY	<=0.002	

COMMENTS:

BAS Laboratories Limited
Consulting Environmental Chemists

14 Abacus Road
Brampton, Ontario
Canada L6T 5B7

Phone (416) 458-4505
Fax (416) 458-7303

Report of analysis

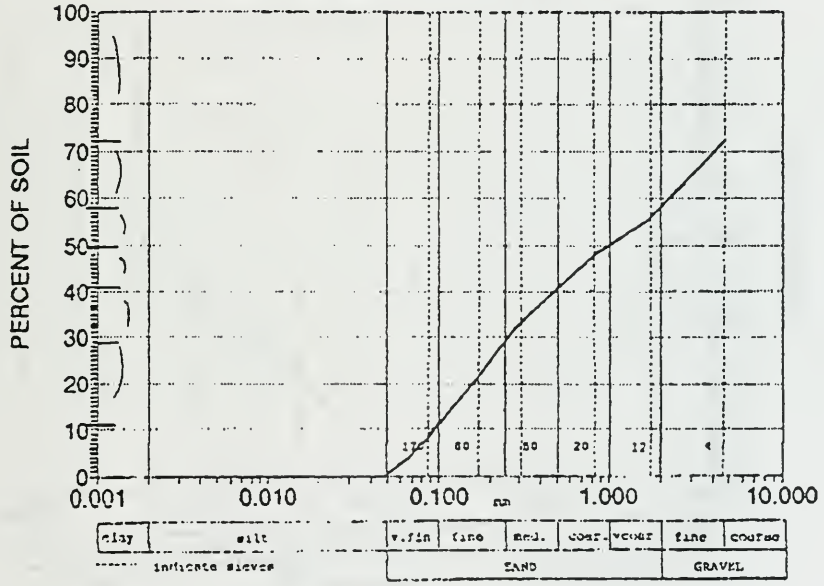
SAMPLE NUMBER: A1-1486-2 SAMPLE NAME: 07-152-2

DATE JULY 26,1991

MOISTURE 0.1 PERCENT

ORGANIC MATTER _____ PERCENT

PARTICLE SIZE



PARTICLE TYPE	SIZE mm	% comp
COARSE GRAVEL	>4.750	24.0
FINE GRAVEL	>2.000-4.750	(4.0
VERY COARSE SAND	>1.000-2.000	8.0
COARSE SAND	>0.500-1.000	9.0
MEDIUM SAND	>0.250-0.500	12.0
FINE SAND	>0.100-0.250	18.0
VERY FINE SAND	>0.050-0.100	11.0
SILT	>0.002-0.050	—
CLAY	<=0.002	—

COMMENTS:

ANALYST: [signature]

Recycled Paper

BAS Laboratories Limited
Consulting Environmental Chemists

14 Abacus Road
Brampton, Ontario
Canada L6T 5B7
Phone (416) 458-4505
Fax (416) 458-7303

Report of analysis

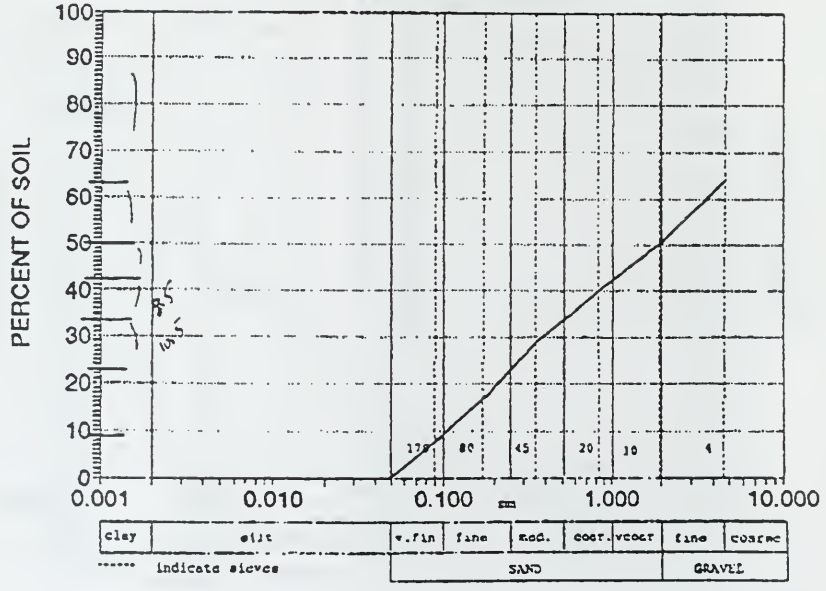
SAMPLE NUMBER: A1-1486-3 SAMPLE NAME: 07-152-03

DATE July 26,1991

MOISTURE 1.0 PERCENT

ORGANIC MATTER _____ PERCENT

PARTICLE SIZE



PARTICLE TYPE	SIZE mm	% ramp
COARSE GRAVEL	>4.750	37.0
FINE GRAVEL	>2.000-4.750	13.0
VERY COARSE SAND	>1.000-2.000	8.0
COARSE SAND	>0.500-1.000	8.6
MEDIUM SAND	>0.250-0.500	10.0
FINE SAND	>0.100-0.250	14.0
VERY FINE SAND	>0.050-0.100	9.0
SILT	>0.002-0.050	—
CLAY	<=0.002	—

COMMENTS:

APPENDIX C

Raw Analytical Data

CANVIRO
Analytical Laboratories Ltd.

REPORT OF ANALYSIS

CLIENT CH2M Hill Engineering Ltd.

ATTENTION Ms. Deborah Ross

ADDRESS 2233 Argentia Road, #302
Mississauga, Ontario
L5N 2X7

PROJECT NO 91-04043

RECEIVED April 1, 1991

REPORTED May 23, 1991

SAMPLE IDENTIFICATION			PARAMETERS FOR ANALYSIS								
LAB NO.	DATE	DESCRIPTION	pH	TS mg/L	CBOD mg/L	NH3-N mg/L	TP mg/L	TOTAL O&G mg/L	CHLORIDE mg/L	SULPHATE mg/L	PHENOL ug/L
04043-01	04/02/91	CALCIUM CHLORIDE-A	8.8	491000	<300	<500	0.10	<1.0	308000	<148	NA
04043-02	04/02/91	CALCIUM CHLORIDE-B	8.8	494000	<300	<500	0.10	<1.0	307000	<148	NA
04043-03	04/02/91	OIL FIELD BRINE-A	5.8	313000	<300	174	0.21	<1.0	156000	<148	NA
04043-04	04/02/91	OIL FIELD BRINE-B	5.8	311000	<300	174	0.27	<1.0	159000	<148	NA
04043-05	04/02/91	TEMBIND-A	4.7	286000	35780	1200	116	780	NA	NA	NA
04043-06	04/02/91	TEMBIND-B	4.7	276000	13880	1100	95.0	840	NA	NA	<1

RESPECTFULLY YOURS

Brent Hodgson

BRENT HODGSON,
LABORATORY SUPERVISOR

THE LIABILITY OF CANVIRO ANALYTICAL LABORATORIES LTD. OR ASSOCIATED FIRMS, EXTENDS ONLY TO THE PRICE OF THE ANALYSIS.

CANVIRO
Analytical Laboratories Ltd.

REISSUED: August 14, 1991

ICAP SCAN

IDENTIFICATION	CALCIUM CHLORIDE A	CALCIUM CHLORIDE B	OIL FIELD BRINE A	OIL FIELD BRINE B	TEMBIND-A	TEMBIND-B
IDENTIFICATION NO.	04043-01	04043-02	04043-03	04043-04	04043-05	04043-06
	CONCENTRATION					
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ALUMINUM	<0.05	<0.05	0.54	0.49	3.84	3.79
BORON	7.31	7.65	6.58	6.39	0.46	0.47
BARIUM	25.9	25.8	0.23	0.23	0.37	0.36
BERYLLIUM	0.066	0.064	0.008	0.008	<0.005	<0.005
CADMIUM	0.040	0.028	<0.012	<0.012	0.034	0.034
CALCIUM	134000	132000	40000	35900	160	155
CHROMIUM	0.05	0.04	<0.02	<0.02	0.08	0.09
COBALT	0.11	0.10	<0.03	<0.03	<0.03	<0.03
COPPER	0.20	0.16	0.04	0.03	0.31	0.30
IRON	1.53	1.44	6.09	6.23	5.78	5.44
LEAD	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
MAGNESIUM	21.7	21.0	2840	2850	31.7	31.0
MANGANESE	0.07	0.06	0.62	0.56	14.8	14.6
VANADIUM	2.44	2.43	0.40	0.41	<0.01	<0.01
ZINC	0.16	0.16	0.30	0.30	1.21	1.19
NICKEL	<0.02	0.04	<0.02	0.03	0.21	0.21
PHOSPHORUS	<1.0	<1.0	<1.0	<1.0	8.48	8.31
SILVER	0.03	<0.02	<0.02	<0.02	<0.02	<0.02
STRONTIUM	31.1	30.7	700	680	0.72	0.67
SODIUM	2435	2900	7070	6270	<5.0	<5.0
ARSENIC	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
SELENIUM	<0.01	<0.01	<0.01	<0.01	0.02	0.02
MERCURY	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

REPORTED BY: CLAUDE IRWIN, TRACE METALS SUPERVISOR

Claude Ch

POLYCHLORINATED DIBENZO-DIOXIN/FURAN ANALYSIS BY "GC/MS"

IDENTIFICATION	TEMBIND-A	MDL For 05	TEMBIND-A DUPLICATE	MDL For DUPL.	LAB BLANK	MDL BLANK
IDENTIFICATION NO.	04043-05		04043-05			
	CONCENTRATION					
	ppt	ppt	ppt	ppt	ppt	ppt
TCDD	<	1.400	<	1.700	<	0.082
TCDF	<	1.100	<	1.300	<	0.064
PCDD	<	1.700	<	2.200	<	0.074
PCDF	<	1.200	<	1.600	<	0.052
H6CDD	<	2.600	<	4.000	<	0.154
H6CDF	<	2.100	<	3.100	<	0.122
H7CDD	TR	2.200	<	9.900	<	0.177
H7CDF	<	1.200	<	2.700	<	0.097
OCDD	2.900	1.500	3.200	2.000	<	0.176
OCDF	<	1.400	<	1.800	<	0.158
% RECOVERY OF SURROGATES						
C13-TCDD	47		38		89	
C13-PCDD	44		38		80	
C13-H6CDD	52		37		75	
C13-H7CDD	83		57		65	
C13-OCDD	123		76		50	

TR - Trace Amount Detected.

CANVIRO
Analytical Laboratories Ltd.

REPORT OF ANALYSIS

CLIENT CH2M Hill Engineering Ltd.

ATTENTION Ms. Deborah Ross

ADDRESS 2233 Argentia Road, #302
Mississauga, Ontario
L5N 2X7

PROJECT NO 91-04044

RECEIVED April 1, 1991

REPORTED May 23, 1991

SAMPLE IDENTIFICATION			PARAMETERS FOR ANALYSIS						
LAB NO.	DATE	DESCRIPTION	pH	TS mg/L	CBOD mg/L	NH3-N mg/L	TP mg/L	TOTAL O&G mg/L	PHENOL ug/L
04044-01	04/02/91	DOMTAR ROAD BINDER-A	8.7	230000	120400	225	149	5530	14900
04044-02	04/02/91	DOMTAR ROAD BINDER-B	8.7	234000	108980	129	190	8270	14900
04044-03	04/02/91	DUST BOND1 WATER5-A	4.9	119000	**	30	117	142000	NA
04044-04	04/02/91	DUST BOND1 WATER5-B	4.9	119000	**	<20	87.4	134000	NA
04044-05	04/02/91	DCS3: WATER 1-A	8.6	59300	29500	<500	145	60400	NA
04044-06	04/02/91	DCS3: WATER 1-B	8.6	59700	16580	<20	160	60800	NA

** - Could not be analyzed as it formed a non-homogeneous emulsion with water.

RESPECTFULLY YOURS

Brent Hodgson

BRENT HODGSON,
LABORATORY SUPERVISOR

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IDENTIFICATION	DOMTAR ROAD BINDER-A	DOMTAR ROAD BINDER-B	DUST BOND1: WATER5-A	DUST BOND1: WATER5-B	DCS3: WATER1-A	DCS3: WATER1-B
IDENTIFICATION NO.	04044-01	04044-02	04044-03	04044-04	04044-05	04044-06
	CONCENTRATION					
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ALUMINUM	3.68	3.19	0.12	0.15	0.05	<0.05
BORON	1.95	2.09	0.07	0.06	0.04	0.08
BARIUM	4.55	4.35	<0.01	<0.01	<0.01	<0.01
BERYLLIUM	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
CADMIUM	0.034	0.033	<0.012	<0.012	<0.012	<0.012
CALCIUM	7.35	5.32	3.00	4.01	4.45	6.25
CHROMIUM	0.03	0.03	<0.02	<0.02	<0.02	<0.02
COBALT	<0.03	0.04	<0.03	<0.03	<0.03	<0.03
COPPER	0.18	0.14	0.02	0.03	0.03	0.05
IRON	2.66	2.32	1.47	1.91	0.56	0.67
LEAD	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
MAGNESIUM	72.4	68.7	0.64	0.89	0.84	1.16
MANGANESE	5.64	5.70	0.01	0.02	<0.01	<0.01
VANADIUM	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
ZINC	4.16	4.16	0.04	0.06	0.01	<0.01
NICKEL	0.11	0.10	<0.02	<0.02	<0.02	<0.02
PHOSPHORUS	43.8	21.5	<1.0	<1.0	<1.0	<1.0
SILVER	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
STRONTIUM	0.27	0.24	0.01	0.02	0.02	0.03
SODIUM	16740	16200	<5.0	<5.0	200	286
ARSENIC	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
SELENIUM	0.03	0.02	<0.01	<0.01	<0.01	<0.01
MERCURY	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

REPORTED BY: CLAUDE IRWIN, TRACE METALS SUPERVISOR

CANVIRO
Analytical Laboratories Ltd.

VOLATILE ORGANIC COMPOUNDS

IDENTIFICATION		LAB BLANK	DUST BOND1: WATER5-A	DUST BOND1: WATER5-B	DCS3: WATER1-A	DCS3: WATER1-B	MDL
IDENTIFICATION NO.			04044-03*	04044-04*	04044-05	04044-06	
NO	COMPOUND	ppb	ppb	ppb	ppb**	ppb**	ppb
1	Chloromethane	<	<	<	<	<	180
2	Vinyl chloride	<	<	<	<	<	250
3	Bromomethane	<	<	<	<	<	100
4	Chloroethane	<	<	<	<	<	80
5	Trichlorofluoromethane	<	<	<	<	<	175
6	Acrolein	<	<	<	<	<	110
7	1,1-Dichloroethylene	<	<	<	<	<	80
8	Methylene Chloride	<	9150	9200	1650	1770	70
9	Acrylonitrile	<	<	<	<	<	105
10	trans-1,2-Dichloroethylene	<	<	<	<	<	35
11	1,1-Dichloroethane	<	<	<	<	<	25
12	Methyl ethyl ketone	<	<	<	<	<	55
13	Chloroform	<	<	<	<	<	20
14	Bromochloromethane	<	<	<	<	<	10
15	1,1,1-Trichloroethane	<	<	<	<	<	25
16	Carbon tetrachloride	<	<	<	<	<	35
17	1,2-Dichloroethene	<	<	<	<	<	15
18	Benzene	<	<	<	<	<	20
19	Trichloroethylene	<	<	<	<	<	95
20	1,2-Dichloropropane	<	<	<	<	<	10
21	Bromodichloromethane	<	<	<	<	<	10
22	2-Chloroethylvinyl ether	<	<	<	<	<	20
23	trans-1,3-Dichloropropylene	<	<	<	<	<	15
24	cis-1,3-Dichloropropylene	<	<	<	<	<	25
25	Toluene	<	180	190	400	380	35
26	1,1,2-Trichloroethane	<	<	<	<	<	15
27	Tetrachloroethylene	<	<	<	<	<	40
28	Dibromochloromethane	<	<	<	<	<	10
29	Ethylene dibromide	<	<	<	<	<	30
30	Chlorobenzene	<	<	<	<	<	10
31	m & p Xylene	<	150	155	1030	975	30
32	Ethyl benzene	<	40.5	41.5	270	260	15
33	Styrene	<	<	<	<	<	20
34	o-Xylene	<	64.0	67.0	530	495	20
35	Bromoform	<	<	<	<	<	15
36	1,1,2,2-Tetrachloroethane	<	<	<	<	<	25
37	1,3-Dichlorobenzene	<	<	<	<	<	10
38	1,4-Dichlorobenzene	<	<	<	<	<	5
39	1,2-Dichlorobenzene	<	<	<	<	<	20
% RECOVERY OF SURROGATES							
d5-Bromoethane		97	56	60	95	87	
d4-1,2-Dichloroethane		95	66	66	108	89	
d8-Toluene		100	49	48	91	86	
Bromochloropropane		98	47	46	88	86	
d10-Ethylbenzene		102	24	24	87	86	

* - Surrogate recoveries are lower due to sample matrix.
** - MDL's are 10x those stated.

CANVIRO
Analytical Laboratories Ltd.

POLYNUCLEAR AROMATIC HYDROCARBONS BY "GC/MS"

IDENTIFICATION	DUST BOND1: WATER5-A	DUST BOND1: WATER5-B	DCS3: WATER1-A	DCS3: WATER1-B	LAB BLANK	RECOVERY SPIKE	MDL
IDENTIFICATION NO.	04044-03	04044-04	04044-05	04044-06			
	ppb	ppb	ppb	ppb	ppb	%	ppb
Naphthalene	90.5	80.7	695	669	<	60	3.2
Acenaphthylene	<	<	<	<	<	67	3.2
Acenaphthene	44.6	37.8	59.8	62.7	<	109	6.4
Fluorene	111	96.0	136	133	<	50	3.2
Phenanthrene	1300	1130	281	292	<	48	5.6
Anthracene	<	<	<	<	<	41	6.4
Fluoranthene	3140	2810	<	<	<	47	4.8
Pyrene	23400	21200	<	<	<	74	3.2
Benzo (a) anthracene	<	<	<	<	<	65	4.0
Chrysene	2890	2660	<	<	<	74	5.6
Benzo (b) fluoranthene	2360	2190	<	<	<	71	5.6
Benzo (k) fluoranthene	*	*	<	<	<	69	5.6
Benzo (a) pyrene	3610	3300	52.6	57.7	<	67	4.8
Indeno (1,2,3-cd) pyrene	<	<	<	<	<	70	8.8
Dibenzo (a,h) anthracene	<	<	<	<	<	69	6.4
Benzo (ghi) perylene	5390	4840	<	<	<	73	7.2
% Recovery Surrogates							
D8-Naphthalene	**	**	**	**	73	74	
D12-Chrysene	**	**	**	**	59	64	

* = Benzo (b) and Benzo (k) fluoranthene co-eluted, therefore result is reported as a total.
** = recovery not possible due to required dilutions.

CANVIRO
Analytical Laboratories Ltd.

POLYCHLORINATED DIBENZO-DIOXIN/FURAN ANALYSIS BY "GC/MS"

IDENTIFICATION	DOMTAR ROAD BINDER A	MDL For 01	DOMTAR RD BINDER A DUPLICATE	MDL For DUPL.
IDENTIFICATION NO.	04044-01		04044-01	
	CONCENTRATION			
	ppt	ppt	ppt	ppt
TCDD	<	0.600	<	0.300
TCDF	<	0.470	<	0.240
PCDD	<	0.074	<	0.330
PCDF	<	0.270	<	0.230
H6CDD	<	0.850	<	0.570
H6CDF	<	0.670	<	0.450
H7CDD	TR	2.700	TR	2.200
H7CDF	<	1.500	<	2.000
OCDD	1.800	1.500	1.400	1.500
OCDF	<	1.400	<	1.400
% RECOVERY OF SURROGATES				
C13-TCDD	48		49	
C13-PCDD	52		45	
C13-H6CDD	44		48	
C13-H7CDD	65		59	
C13-OCDD	58		53	

TR - Trace Amount Detected.

CANVIRO
Analytical Laboratories Ltd.

REPORT OF ANALYSIS

NT CH2M Hill Engineering Ltd.
NTION Deborah Ross
ESS 2233 Argentia Road, Suite 302
Mississauga, Ontario
L5N 2X7

PROJECT NO. 91-04045
RECEIVED April 1, 1991
REPORTED May 10, 1991

SAMPLE IDENTIFICATION			PARAMETERS FOR ANALYSIS				
AB NO.	DATE	DESCRIPTION	pH	TS mg/L	CBOD mg/L	NH3-N mg/L	T.P. mg/L
045-01	04/02/91	Petro Wash Oil A:A	7.8	553,000	*	<500	29.4
045-02	04/02/91	Petro Wash Oil A:B	7.8	570,000	*	<500	32.3
045-03	04/02/91	Breslube Oil A	9.7	746,000	*	<500	16.4
045-04	04/02/91	Breslube Oil B	9.7	718,000	*	<500	17.7

Not Analyzed - Insoluble Oil.

RESPECTFULLY YOURS

Brent Hodgson

BRENT HODGSON,
LABORATORY SUPERVISOR

LIABILITY OF CANVIRO ANALYTICAL LABORATORIES LTD. OR ASSOCIATED FIRMS,
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CANVIRO
Analytical Laboratories Ltd.

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IDENTIFICATION	PETRO WASH OIL A:A	PETRO WASH OIL A:B	BRESLUBE OIL A	BRESLUBE OIL B
IDENTIFICATION NO.	04045-01	04045-02	04045-03	04045-04
	CONCENTRATION			
	mg/L	mg/L	mg/L	mg/L
ALUMINUM	<2	3	3	5
BORON	3	8	5	10
BARIUM	<2	<2	<2	<2
BERYLLIUM	<0.5	<0.5	<0.5	<0.5
CADMIUM	<0.2	<0.2	<0.2	<0.2
CALCIUM	<5	<5	<5	5
CHROMIUM	<0.5	<0.5	<0.5	<0.5
COBALT	<0.5	<0.5	<0.5	<0.5
COPPER	<0.5	<0.5	<0.5	<0.5
IRON	<0.5	<0.5	<0.5	<0.5
LEAD	<1	<1	<1	<1
MAGNESIUM	2	<0.5	2	2
MANGANESE	<0.5	<0.5	<0.5	<0.5
VANADIUM	<0.5	<0.5	<0.5	<0.5
ZINC	<1	<1	<1	<1
NICKEL	<0.5	2	<0.5	<0.5
PHOSPHORUS	<10	<10	<10	<10
SILVER	<0.5	<0.5	<0.5	<0.5
STRONTIUM	<0.5	<0.5	<0.5	<0.5
SODIUM	10	10	10	10
MOLYBDENUM	<0.5	<0.5	<0.5	<0.5
POTASSIUM	<5	5	<5	<5
ARSENIC	<0.2	<0.2	<0.2	<0.2
SELENIUM	<0.1	<0.1	<0.1	<0.1
MERCURY	<0.02	<0.02	<0.02	<0.02

REPORTED BY: CLAUDE IRWIN, TRACE METALS SUPERVISOR

Claude

CANVIRO
Analytical Laboratories Ltd.

REPORT OF ANALYSIS

CLIENT CH2M Hill Engineering Ltd.
ATTENTION Deborah Ross
ADDRESS 2233 Argentia Road, Suite 302
Mississauga, Ontario
L5N 2X7

PROJECT NO. 91-04045
RECEIVED April 1, 1991
REPORTED May 10, 1991

Polychlorinated Biphenyls (PCB's) - by "GC/MS"

IDENTIFICATION	BRESLUBE OIL A	BRESLUBE OIL B	LAB BLANK	RECOVERY SPIKE	MDL
IDENTIFICATION NO.	04045-03	04045-04			
	ppb	ppb	ppb	%	ppb
PCB - 1242	<	<	<	78	120
PCB - 1254	<	<	<	97	256
PCB - 1260	<	<	<	94	256
TOTAL PCB	ND	ND	ND		
% RECOVERY OF SURROGATE					
2,4,6-TBB	*	*	78	74	

ND = Not Detected
* - Recovery not possible due to required dilution.

RESPECTFULLY YOURS

JEANINE WAUGH,
TRACE ORGANICS SUPERVISOR

HE LIABILITY OF CANVIRO ANALYTICAL LABORATORIES LTD. OR ASSOCIATED FIRMS,
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CANVIRO
Analytical Laboratories Ltd.

POLYNUCLEAR AROMATIC HYDROCARBONS BY "GC/MS"

IDENTIFICATION	PETRO WASH OIL A:A	PETRO WASH OIL A:B	BRESLUBE OIL A	MDL
IDENTIFICATION NO.	04045-01	04045-02	04045-03	
	ppb	ppb	ppb	ppb
Naphthalene	1,780	1,640	18,200	80
Acenaphthylene	<	<	<	80
Acenaphthene	47,800	29,200	9,170	160
Fluorene	<	<	19,500	80
Phenanthrene	<	<	128,000	140
Anthracene	<	<	<	160
Fluoranthene	3,970	4,050	20,600	120
Pyrene	6,140	6,140	64,500	80
Benzo (a) anthracene	<	<	13,500	100
Chrysene	<	<	24,100	140
Benzo (b) fluoranthene	<	<	<	140
Benzo (k) fluoranthene	<	<	<	140
Benzo (a) pyrene	<	<	9,310	140
Indeno (1,2,3-cd) pyrene	<	<	2,570	220
Dibenzo (a,h) anthracene	<	<	<	160
Benzo (ghi) perylene	<	<	6,020	180
% RECOVERY OF SURROGATES				
D8-Naphthalene	*	*	*	
D12-Chrysene	*	*	*	

* - Recovery not possible due to required dilution

CANVIRO
Analytical Laboratories Ltd.

POLYNUCLEAR AROMATIC HYDROCARBONS BY "GC/MS"

IDENTIFICATION	BRESLUBE OIL A	LAB BLANK	RECOVERY SPIKE	MDL
IDENTIFICATION NO.	04045-04			
	ppb	ppb	%	ppb
Naphthalene	17,400	<	60	80
Acenaphthylene	<	<	67	80
Acenaphthene	8,130	<	109	160
Fluorene	18,900	<	50	80
Phenanthrene	121,000	<	48	140
Anthracene	<	<	41	160
Fluoranthene	19,700	<	47	120
Pyrene	62,400	<	74	80
Benzo (a) anthracene	12,300	<	65	100
Chrysene	23,600	<	74	140
Benzo (b) fluoranthene	<	<	71	140
Benzo (k) fluoranthene	<	<	69	140
Benzo (a) pyrene	9,240	<	67	140
Indeno (1,2,3-cd) pyrene	4,020	<	70	220
Dibenzo (a,h) anthracene	<	<	69	160
Benzo (ghi) perylene	5,490	<	73	180
% RECOVERY OF SURROGATES				
D8-Naphthalene	*	73	74	
D12-Chrysene	*	59	64	

* - Recovery not possible due to required dilution

CANVIRO
Analytical Laboratories Ltd.

VOLATILE ORGANIC COMPOUNDS

IDENTIFICATION		PETRO WASH OIL A:A *	PETRO WASH OIL A:B *	BRESLUBE OIL A **	BRESLUBE OIL B **	LAB BLANK	MDL
IDENTIFICATION NO.		04045-01	04045-02	04045-03	04045-04		
NO	COMPOUND	ppb	ppb	ppb	ppb	ppb	ppb
1	Chloromethane	<	<	<	<	<	3.6
2	Vinyl chloride	<	<	<	<	<	5.0
3	Bromomethane	<	<	<	<	<	2.0
4	Chloroethane	<	<	<	<	<	1.6
5	Trichlorofluoromethane	<	<	<	<	<	3.5
6	Acrolein	<	<	<	<	<	2.2
7	1,1-Dichloroethylene	<	<	<	<	<	1.6
8	Methylene Chloride	<	<	<	<	<	1.8
9	Acrylonitrile	<	<	<	<	<	2.1
10	trans-1,2-Dichloroethylene	<	<	<	<	<	0.7
11	1,1-Dichloroethane	<	<	<	<	<	0.5
12	Methyl ethyl ketone	<	<	2,070	2,900	<	1.1
13	Chloroform	<	<	770	1,200	<	0.4
14	Bromochloromethane	<	<	<	<	<	0.2
15	1,1,1-Trichloroethane	<	<	<	<	<	0.5
16	Carbon tetrachloride	<	<	<	<	<	0.7
17	1,2-Dichloroethane	<	<	<	<	<	0.3
18	Benzene	<	<	<	<	<	0.4
19	Trichloroethylene	<	<	<	<	<	1.9
20	1,2-Dichloropropane	<	<	<	<	<	0.2
21	Bromodichloromethane	<	<	<	<	<	0.2
22	2-Chloroethylvinyl ether	<	<	<	<	<	0.6
23	trans-1,3-Dichloropropylene	<	<	<	<	<	0.3
24	cis-1,3-Dichloropropylene	<	<	<	<	<	0.5
25	Toluene	<(25.0)	<(22.5)	2,800	3,770	<	0.7
26	1,1,2-Trichloroethane	<	<	<	<	<	0.3
27	Tetrachloroethylene	<	<	<	<	<	0.8
28	Dibromochloromethane	<	<	<	<	<	0.2
29	Ethylene dibromide	<	<	<	<	<	0.6
30	Chlorobenzene	<	<	<	<	<	0.2
31	m & p Xylene	40.0	39.0	580	800	<	0.6
32	Ethyl benzene	15.0	15.0	375	500	<	0.3
33	Styrene	<	<	<	<	<	0.4
34	o-Xylene	20.0	20.5	1,300	1,800	<	0.4
35	Bromoform	<	<	<	<	<	0.3
36	1,1,2,2-Tetrachloroethane	<	<	<	<	<	0.5
37	1,3-Dichlorobenzene	<	<	<	<	<	0.2
38	1,4-Dichlorobenzene	<	<	<	<	<	0.1
39	1,2-Dichlorobenzene	<	<	<	<	<	0.4
% RECOVERY OF SURROGATES							
d5-Bromoethane		96	95	80	108	97	
d4-1,2-Dichloroethane		88	84	79	105	95	
d8-Toluene		26	28	80	104	100	
Bromochloropropane		31	33	78	99	98	
d10-Ethylbenzene		15	18	76	102	102	

NOTE: Samples have NOT been corrected for laboratory blank.
* - Surrogate Recoveries lower due to sample matrix.
** - MDL's are 10x those stated, due to required dilutions

CANVIRO
Analytical Laboratories Ltd.

REPORT OF ANALYSIS

ENT CH2M Hill Engineering Ltd.
ENTION Deborah Ross
RESS 2233 Argentia Road, Suite 302
Mississauga, Ontario
L5N 2X7

PROJECT NO. 91-04216
RECEIVED April 19, 1991
REPORTED May 10, 1991

SAMPLE IDENTIFICATION			PARAMETERS FOR ANALYSIS				
LAB NO.	DATE	DESCRIPTION	pH	TS %	CBOD mg/L	NH3-N mg/L	T.P. mg/L
216-01	04/18/91	Burner Fuel - 9	5.0	61	*	<500	*
216-02	04/18/91	Dark Journal Oil	3.7	46	*	<500	*

Not Analyzed - Insoluble Oil.

RESPECTFULLY YOURS

Brent Hodgson

BRENT HODGSON,
LABORATORY SUPERVISOR

LIABILITY OF CANVIRO ANALYTICAL LABORATORIES LTD. OR ASSOCIATED FIRMS,
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ICAP SCAN

IDENTIFICATION	BURNER FUEL - 9	DARK JOUNRAL OIL
IDENTIFICATION NO.	04216-01	04126-02
	mg/L	mg/L
ALUMINUM	10	2
BORON	20	4
BARIUM	<2	<2
BERYLLIUM	<0.5	<0.5
CADMIUM	<0.2	<0.2
CALCIUM	10	<5
CHROMIUM	<0.5	<0.5
COBALT	<0.5	<0.5
COPPER	<0.5	<0.5
IRON	6	<0.5
LEAD	<1	<1
MAGNESIUM	5	<5
MANGANESE	<0.5	<0.5
VANADIUM	17	<0.5
ZINC	4	<1
NICKEL	10	<0.5
PHOSPHORUS	<10	<10
SILVER	<0.5	<0.5
STRONTIUM	<0.5	<0.5
SODIUM	50	10
ARSENIC	<0.2	<0.2
SELENIUM	<0.2	<0.2
MERCURY	<0.02	<0.02

REPORTED BY: CLAUDE IRWIN, TRACE METALS SUPERVISOR

CANVIRO
Analytical Laboratories Ltd.

POLYNUCLEAR AROMATIC HYDROCARBONS BY "GC/MS"

IDENTIFICATION	* BURNER FUEL -9	DARK JOURNAL OIL	LAB BLANK	RECOVERY SPIKE	MDL
IDENTIFICATION NO.	04216-01	04216-02			
	ppb	ppb	ppb	%	ppb
Naphthalene	185000	<	<	49	6.4
Acenaphthylene	<	<	<	131	6.4
Acenaphthene	<	<	<	127	12.8
Fluorene	291000	<	<	111	6.4
Phenanthrene	596000	<	<	103	11.2
Anthracene	<	<	<	89	12.8
Fluoranthene	<	<	<	80	9.6
Pyrene	11400	<	<	97	6.4
Benzo (a) anthracene	<	<	<	135	8.0
Chrysene	<	<	<	143	11.2
Benzo (b) fluoranthene	<	<	<	155	11.2
Benzo (k) fluoranthene	<	<	<	132	11.2
Benzo (a) pyrene	<	<	<	137	9.6
Indeno (1,2,3-cd) pyrene	<	<	<	140	17.6
Dibenzo (a,h) anthracene	<	<	<	136	12.8
Benzo (ghi) perylene	<	<	<	136	14.4
% RECOVERY OF SURROGATES					
D8-Naphthalene	**	62	50	56	
D12-Chrysene	**	***	108	133	

* MDL is 10X higher due to required dilution.
** Recovery not possible due to required dilution.
** Recovery not possible due to matrix interference.

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VOLATILE ORGANIC COMPOUNDS

IDENTIFICATION		LAB BLANK	* BURNER FUEL -9	DARK JOURNAL OIL	MDL
IDENTIFICATION NO.			04216-01	04216-02	
NO	COMPOUND	ppb	ppb	ppb	ppb
1	Chloromethane	<	<	<	360
2	Vinyl chloride	<	<	<	500
3	Bromomethane	<	<	<	200
4	Chloroethane	<	<	<	160
5	Trichlorofluoromethane	<	<	<	350
6	Acrolein	<	<	<	220
7	1,1-Dichloroethylene	<	<	<	160
8	Methylene Chloride	<	<	<	180
9	Acrylonitrile	<	<	<	210
10	trans-1,2-Dichloroethylene	<	<	<	70
11	1,1-Dichloroethane	<	<	<	50
12	Methyl ethyl ketone	<	67,000	710	110
13	Chloroform	<	10,000	300	40
14	Bromochloromethane	<	<	<	20
15	1,1,1-Trichloroethane	<	<	<	50
16	Carbon tetrachloride	<	<	230	70
17	1,2-Dichloroethane	<	<	<	30
18	Benzene	<	24,700	65.0	40
19	Trichloroethylene	<	<	<	190
20	1,2-Dichloropropane	<	<	<	20
21	Bromodichloromethane	<	<	<	20
22	2-Chloroethylvinyl ether	<	<	<	40
23	trans-1,3-Dichloropropylene	<	<	<	30
24	cis-1,3-Dichloropropylene	<	<	<	50
25	Toluene	<	119,600	170	70
26	1,1,2-Trichloroethane	<	<	<	30
27	Tetrachloroethylene	<	<	<	80
28	Dibromochloromethane	<	<	<	20
29	Ethylene dibromide	<	<	<	60
30	Chlorobenzene	<	<	<	20
31	m & p Xylene	<	231,500	98.0	60
32	Ethyl benzene	<	55,100	32.0	30
33	Styrene	<	<	<	40
34	o-Xylene	<	109,400	<(31.0)	40
35	Bromoform	<	<	<	30
36	1,1,2,2-Tetrachloroethane	<	<	<	50
37	1,3-Dichlorobenzene	<	<	<	20
38	1,4-Dichlorobenzene	<	<	<	10
39	1,2-Dichlorobenzene	<	<	<	40
% RECOVERY OF SURROGATES					
d5-Bromoethane		112	109	102	
d4-1,2-Dichloroethane		108	106	99	
d8-Toluene		117	119	103	
Bromochloropropane		113	120	99	
d10-Ethylbenzene		122	138	95	

NOTE: Samples have NOT been corrected for laboratory blank.
* - MDL's are 100X those stated due to dilution.
<( ) - Positive identification but below MDL.

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Analytical Laboratories Ltd.

REPORT OF ANALYSIS

NT CH2M Hill Engineering Ltd.

NTION Ms. Deborah Ross

ESS 2233 Argentia Road, #302,
Mississauga, Ontario
L5N 2X7

PROJECT NO 91-05113

RECEIVED May 14, 1991

REPORTED June 21, 1991

SAMPLE IDENTIFICATION			PARAMETERS FOR ANALYSIS			
AB NO.	DATE	DESCRIPTION	AMMONIA as NH3-N mg/L	TOTAL PHOSPHORUS mg/L	pH	TOTAL SOLIDS %
113-01	04/18/91	Burner Fuel - 9 (2)	<100	*	7.1	35
113-02	04/18/91	Dark Journal Oil (2)	<100	*	6.7	99

Total Phosphorus Samples Declined

RESPECTFULLY YOURS

BRENT HODGSON,
LABORATORY SUPERVISOR

LIABILITY OF CANVIRO ANALYTICAL LABORATORIES LTD. OR ASSOCIATED FIRMS,
NDS ONLY TO THE PRICE OF THE ANALYSIS.

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METALS (ICAP SCAN)

IDENTIFICATION	BURNER FUEL - 9 (2)	DARK JOURNAL OIL (2)
IDENTIFICATION NO.	05113-01	05113-02
	mg/L	mg/L
ZINC	5	3
CADMIUM	<0.5	<0.5
LEAD	<2	<2
COBALT	<1	<1
NICKEL	15	5
IRON	2	<2
BORON	4	6
MANGANESE	<1	<1
CHROMIUM	<1	<1
MAGNESIUM	<5	5
VANADIUM	19	<1
BERYLLIUM	<1	<1
CALCIUM	10	5
COPPER	<0.5	<0.5
SILVER	<0.5	<0.5
ALUMINUM	<2	<2
STRONTIUM	<1	<1
BARIUM	<1	<1
SODIUM	<50	<50
PHOSPHORUS (TOTAL)	<10	<10
MERCURY	<10	<10
ARSENIC	<100	<100
SELENIUM	<100	<100

REPORTED BY: CLAUDE IRWIN, TRACE METALS SUPERVISOR

Angela Conacity for

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POLYNUCLEAR AROMATIC HYDROCARBONS BY "GC/MS"

IDENTIFICATION	BURNER FUEL-9 (2) *	DARK JOURNAL OIL (2)	MDL
IDENTIFICATION NO.	05113-01	05113-02	
	ppm	ppb	ppb
Naphthalene	125	<	6.4
Acenaphthylene	<	<	6.4
Acenaphthene	<	<	12.8
Fluorene	84.0	<	6.4
Phenanthrene	334	<	11.2
Anthracene	<	<	12.8
Fluoranthene	<	<	9.6
Pyrene	11.2	<	6.4
Benzo (a) anthracene	<	<	8.0
Chrysene	<	<	11.2
Benzo (b) fluoranthene	<	<	11.2
Benzo (k) fluoranthene	<	<	11.2
Benzo (a) pyrene	<	<	9.6
Indeno (1,2,3-cd) pyrene	<	<	17.6
Dibenzo (a,h) anthracene	<	<	12.8
Benzo (ghi) perylene	<	<	14.4
% RECOVERY OF SURROGATES			
D8-Naphthalene	**	89	
D12-Chrysene	**	**	

* - MDL is 10x higher than listed due to required dilution.
** - Recovery not possible due to required dilution and matrix interference.

ppm = ug/mL
ppb = ng/mL

CANVIRO
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VOLATILE ORGANIC COMPOUNDS

IDENTIFICATION		LAB BLANK	BURNER FUEL-9 (2) *	DARK JOURNAL OIL (2)**	MDL
IDENTIFICATION NO.			05113-01	05113-02	
NO	COMPOUND	ppb	ppb	ppb	ppb
1	Chloromethane	NA	NA	NA	---
2	Vinyl chloride	NA	NA	NA	---
3	Bromomethane	NA	NA	NA	---
4	Chloroethane	NA	NA	NA	---
5	Trichlorofluoromethane	<	<	<	350
6	Acrolein	<	<	<	220
7	1,1-Dichloroethylene	<	<	<	160
8	Methylene Chloride	<	<	<	180
9	Acrylonitrile	<	<	<	210
10	trans-1,2-Dichloroethylene	<	<	<	70
11	1,1-Dichloroethane	<	<	<	50
12	Methyl ethyl ketone	<	74,000	790	110
13	Chloroform	<	8,400	64	40
14	Bromochloromethane	<	<	<	20
15	1,1,1-Trichloroethane	<	<	<	50
16	Carbon tetrachloride	<	<	130	70
17	1,2-Dichloroethane	<	<	<	30
18	Benzene	<	15,400	<	40
19	Trichloroethylene	<	<	<	190
20	1,2-Dichloropropane	<	<	<	20
21	Bromodichloromethane	<	<	<	20
22	2-Chloroethylvinyl ether	<	<	<	40
23	trans-1,3-Dichloropropylene	<	<	<	30
24	cis-1,3-Dichloropropylene	<	<	<	50
25	Toluene	<	86,100	140	90
26	1,1,2-Trichloroethane	<	<	<	30
27	Tetrachloroethylene	<	<	<	80
28	Dibromochloromethane	<	<	<	20
29	Ethylene dibromide	<	<	<	60
30	Chlorobenzene	<	<	<	20
31	m & p Xylene	<	173,000	<(21.0)	60
32	Ethyl benzene	<	39,600	<	30
33	Styrene	<	<	<	40
34	o-Xylene	<	84,900	<	40
35	Bromoform	<	<	<	30
36	1,1,2,2-Tetrachloroethane	<	<	<	50
37	1,3-Dichlorobenzene	<	<	<	20
38	1,4-Dichlorobenzene	<	<	<	10
39	1,2-Dichlorobenzene	<	<	<	40
% RECOVERY OF SURROGATES					
d5-Bromoethane		101	89	59	
d4-1,2-Dichloroethane		101	101	62	
d8-Toluene		98	96	31	
Bromochloropropane		98	102	40	
d10-Ethylbenzene		98	104	20	

* - MDL's are 100x those shown due to required dilution.
** - Surrogate Recoveries Low due to sample matrix.
<( ) - Positive identification but below MDL.

APPENDIX D

Report on Acute Toxicity Testing

Study Title

Acute Toxicity of Dust Suppressants
To *Daphnia magna* and Rainbow trout
Under Static Test Conditions

DRAFT

Author

Keith Holtze

Experimental Termination Date: July 16, 1991

Report Completion Date: July 30, 1991

Performing Laboratory

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Report #030104

Authentication

I the undersigned, hereby declare that this work was performed under my direction and in accordance with the general procedures outlined by the Ontario Ministry of the Environment for conducting toxicity tests with *Daphnia magna* (Poirier *et al.* 1988) and rainbow trout (Craig *et al.* 1983). The study was conducted according to the procedure herein described and this report represents a true and accurate record of the results obtained.

_____
Keith Holtze
Study Director

Date _____

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APPENDIX D: SUMMARY OF TEST CONDITIONS AND CALCULATIONS USED FOR CONDUCTING DEFINITIVE BIOASSAYS

APPENDIX E: DEFINITIVE TEST RESULTS - RAW DATA REPORTS

SUMMARY

A study was conducted to determine the acute toxicity of traditional dust suppressants to rainbow trout (*Oncorhynchus mykiss*) and an aquatic invertebrate, *Daphnia magna*. A total of ten substances were tested for their toxicity to fish and *Daphnia* including (1) six petroleum products consisting of virgin oils (bunker fuel, Petro Canada wash oil, dark journal oil), one re-refined oil (Breslube), one petroleum based resin/surfactant mixture (Dust Bond) and one oil/asphalt/water mixture (DCS-2); (2) two pulping liquors, Domtar Road Binder (unknown composition) and an ammonium lignosulphonate pulping liquor (Tembind), (3) calcium chloride and (4) brine (Oil Field brine).

Range finding tests were performed on all materials to determine the approximate response range for each test species. Based on these results, definitive tests were conducted to determine the LC50 (median lethal concentration) or EC50 (median effective concentration) for each material. The LC50 is the concentration of material in water that is estimated to be lethal to 50% of the test organisms after a defined period of exposure (e.g., 96 hr LC50). Each definitive test consisted of exposing a minimum of twenty test organisms to five or more concentrations of the test material (e.g. 1,000, 1,600, 2,500, 4,000, 6,000 and 10,000 ppm) plus a dilution water control.

Four products including Bunker Fuel, Dark Journal Oil, Breslube, and Petro Canada Wash Oil were insoluble in water. For these substances, estimates of acute toxicity to fish and *Daphnia* were based on exposure of the test animals to the water soluble fraction of the test material (i.e. that which would dissolve in water after a period up to and including 96 hours). All of the remaining products tested readily dissolved in water. For these substances, toxicity was estimated on the basis of the whole product. All LC50 estimates were derived using nominal concentrations of the test material.

1.0 INTRODUCTION

B.A.R. Environmental Inc. was contracted by CH_2MHILL to conduct a study to determine the acute toxicity of dust suppressants to rainbow trout (*Oncorhynchus mykiss*) and an aquatic invertebrate, *Daphnia magna* (water flea). By definition, acute toxic effects are those which occur within a relatively short period of time (conventionally within four days). These effects may be lethal or sublethal. This distinction is emphasized here inasmuch as the literature not uncommonly, but also incorrectly, equates the terms "acute toxicity" or "acutely toxic" as synonymous with acute lethal toxicity, ignoring acute sublethal toxic effects. For the purpose of this report, we will refer to acute lethal toxicity.

Preliminary range finding tests were conducted by BAR to determine the approximate response range of trout and *Daphnia* for each of the test materials. Definitive bioassays were then carried out to determine the LC50 (median lethal concentration) or the EC50 (median effective concentration). The LC50 is the concentration of material in water that is estimated to be lethal to 50% of the test organisms within a defined period of exposure. The EC50 refers to the concentration that is estimated to induce a specified non-lethal effect (eg. immobility) or lethal effect on 50% of the test organisms. This report presents the results of the toxicity study and describes the technical approach used to meet the project objectives.

2.0 METHODS AND MATERIALS

2.1 Dilution Water

Natural groundwater was used as a source of dilution water in all tests. The water was filtered through a 20 micron cellulose-acetate filter and subsequently sterilized using ultra violet radiation. A continuous supply of oil-free compressed air was provided to bring the pH and concentration of dissolved oxygen and other gases into equilibrium with air and reduce oxygen demand. The concentration of dissolved oxygen in the dilution water was maintained at >70% of the air saturation value.

Water used for the culture of fish and *Daphnia* was identical to that used for testing purposes. Bioassays with fish were conducted in natural ground water (hardness = 260 mg/L as $CaCO_3$). Bioassays with *Daphnia* were conducted in ground water diluted with reverse-osmosis treated water to obtain a total hardness level of approximately 160 mg/L as $CaCO_3$. The chemical characteristics of the dilution waters are provided in Appendix A.

2.2 Test Organisms

Rainbow trout (<1 gm) were obtained from a licensed fish hatchery in Ontario (Rainbow Springs Trout Farm, Thamesford, Ontario). The fish were certified disease free as described in Schedule B of the Fish Health Protection Regulation under the Fisheries Act of Canada. Fish were held in square plastic tanks provided with a continuous supply of well aerated water at 15 ± 1°C. Artificial lighting (40 to 50 foot-candles) was provided on a controlled lighting regime of 16 hours light and 8 hours dark. Fish were fed commercial trout chow at a rate of 4% of body weight per day.

Daphnia magna were obtained from in-house cultures that have been maintained by BAR since 1988. The initial brood stock was obtained from the Aquatic Biology Unit, Ministry of the Environment, Rexdale, Ontario. *Daphnia* were cultured in water maintained at 20 ± 1°C. Organisms were fed a suspension of unicellular algae (*Selenastrum capricornutum* and *Chlorella fusca*). Artificial lighting (40 to 50 foot-candles) was provided on a controlled lighting regime of 16 hours light and 8 hours dark. *Daphnia* cultures were culled at regular intervals to maintain log phase growth and prevent production of ephippia (fertilized eggs). Gravid adults were separated from the culture stock and individually placed in 250 mL glass beakers filled with culture water. Organisms for testing were separated from the actively reproducing cultures. Only first-instar *Daphnids* (<24 hr old) were used in tests.

2.3 Test Material

Samples of dust suppressants were received from CH_2M HILL for testing between March 20 and April 23, 1991. Initial sample volumes of calcium chloride and Oil Field Brine were not sufficient to complete all tests and so additional samples were obtained. All products were submitted in liquid form. Samples were diluted to the manufacturer's specifications prior to testing.

A total of ten substances were tested for their toxicity to fish and *Daphnia* including (1) petroleum products consisting of three virgin oils (bunker fuel, Petro Canada wash oil, dark journal oil), one re-refined oil (Breslube), one petroleum based resin/surfactant mixture (Dust Bond) and one oil/asphalt/water mixture (DCS-2); (2) an ammonium lignosulphonate pulping liquor (Tembind), (3) calcium chloride and (4) brine (Oil Field brine). The materials were stored at room temperature prior to testing.

2.4 Preparation of Test Solutions

Different methods were used to prepare the test solutions, depending on the solubility of the product in water. For those substances which readily dissolved in water, multiple concentrations of the test material were prepared by adding measured volumes of the test substance (undiluted) or stock solution to the laboratory dilution water. Stock solutions, if

required, were prepared by dissolving the test material in deionized water at 20°C. For those products that did not readily dissolve in water (Petro Canada Wash Oil, Breslube, Dark Journal Oil, Bunker Fuel), organic solvents were used to increase solubility. Three solvents including methanol, acetone and triethylene glycol were used at the maximum recommended rate of 0.5 mL of solvent per Litre of dilution water (U.S. EPA 1985). One product, Petro Canada Wash Oil, dissolved in acetone but only at a very low concentration (≤ 2,000 ppm). Furthermore, oil droplets formed when the stock solution was added to the dilution water. As such, an alternate method of preparing the test solutions was developed as a result of discussions with Dave Poirier, Aquatic Biology Unit, Ministry of the Environment.

For those products that did not readily dissolve in water, tests were carried out on the water soluble fraction of the material (i.e. that which would dissolve in water after an extended period of exposure). For these materials, test solutions having a nominal concentration of 10,000 ppm product were prepared by adding 20 mL of product to 20 L of dilution water. The solutions were stored @ 15°C for 24 and 96 hours prior to testing. Oil-free compressed air was supplied during this time to provide gently mixing of the solution. At the end of the storage period, the solution to be tested was removed from the test container by siphoning off the liquid and transferring this material to a new, clean test container.

2.5 Test Procedures

All products were assessed for their acute toxicity to trout and *Daphnia* using the procedures developed by the Ontario Ministry of the Environment. These included the 48 hour acute lethality test using *Daphnia magna* (Poirier et al. 1988) and the 96 hour acute lethality test using rainbow trout (Craig *et al.* 1983). The general test procedures are described below.

Bioassays with trout were conducted in plastic exposure chambers, fitted with a food-grade polyethylene liner, containing 20 L of test solution. Testing temperatures and photoperiod were similar to those of culture or holding conditions and kept constant between all tests. The tests were conducted in temperature controlled water baths held at 15 ± 1°C. Feeding of the test fish was terminated 24 hours prior to the start of the test. Solutions were gently aerated (oil-free compressed air) throughout the 96 hour exposure period. All tests were conducted under static conditions with no renewal of the test solution.

Observations for immobility or mortality were made and recorded after 4, 24, 48, 72 and 96 hours (final observation). A fish was considered dead if there was no evidence of opercular or other activity and no response to gentle prodding.

Bioassays with *Daphnia* were conducted at 20 ± 1°C in clean glass test tubes (25 X 150 mm) containing 50 mL of solution. All tests were initiated using first-instar neonates (<24 hr old). Three neonates were randomly placed into each of four replicate test chambers for

a total of twelve animals per concentration. Each test included at least one group of control organisms in 100% laboratory dilution water, but otherwise exposed to the same conditions as the test specimens. Testing temperature and photoperiod were similar to those during the holding period prior to testing and kept constant during all tests. Test solutions were not aerated during the 48 hour exposure period.

Observations for immobility or mortality were made and recorded after 24, and 48 hours (final observation). A Daphnid was considered to be dead if there was no visible heart beat upon microscopic examination. Records were made of all other signs of stress during, and at completion of the bioassay.

Measurements of conductivity, pH and dissolved oxygen levels in each test solution including the control were made at the beginning and at the end of the test. Water temperature was measured and recorded at each observation period.

A test was considered to be invalid if more than ten percent (>1 out of ten animals) of the control animals exhibited atypical/stressed behaviour and/or mortality.

2.5.1 Range Finding Bioassays

Range finding tests were conducted to determine the approximate response range for fish and *Daphnia*. Test animals were exposed to four or more nominal concentrations of the test material (e.g. 1.0, 10, 100, 1,000, and 10,000 ppm) plus a control consisting of laboratory dilution water alone. A minimum of ten animals were randomly added to each exposure chamber. Test solutions were not renewed during the exposure. A summary of the test conditions for each individual test is provided in Appendix C.

2.5.2 Definitive Bioassay

The standard LC50 approach (i.e. using multiple concentrations) was used to estimate toxicity to trout and *Daphnia* for those products that readily dissolved in water. Appropriate concentrations for testing were determined from the results of the range finding tests. Each test consisted of five or more exposure concentrations plus a dilution water control. All other test conditions were similar to those used to conduct the range finding bioassays except that the tests were conducted in duplicate with a total of twenty or more organisms per test level.

These standard procedures were modified to permit the testing of the insoluble oil products. For bioassays with fish, test animals were exposed to a single test solution containing 10,000 ppm (nominal concentration) of product that had been allowed to stand for 24 and 96 hours prior to testing. In the event that the solution did not kill more than 50% of the fish, then no further testing was performed. If, however, more than 50% mortality occurred, then an

additional 60 L of test solution was prepared, as before, and a multiple concentration test was performed to determine the 96 Hr. LC50. For tests with *Daphnia*, multiple concentration tests were performed using procedures similar to those used to test the water soluble products, except that nominal exposure concentrations were limited to a maximum concentration of 10,000 ppm.

2.6 Data Analysis

Median lethal (LC50) concentrations and their 95% Confidence Intervals were calculated using survival data at the end of the test and nominal test concentrations by the probit analysis method (Stephan 1977). The LC50 concentration is defined as the concentration of material in water that is lethal to 50% of the test organisms after a defined period of exposure. LC50 values reported for the water soluble products were based on nominal concentrations of the whole product, while LC50s for the insoluble oil products were based on the water soluble fraction.

3.0 Results

Table 1 provides a summary of the acute toxicity of the dust suppressant materials to rainbow trout and *Daphnia magna*. Table values include the LC50 (median lethal) and/or EC50 (median effective concentration) and their 95% confidence intervals. The raw data including mortality observations and chemical analyses performed during the test are provided in Appendix E.

3.1 Petroleum Products

Bunker Fuel (Water Soluable Fraction)

Bunker Fuel was determined to be non-lethal to both trout and *Daphnia* at 10,000 ppm after aging the sample for 24 and 96 hours.

Petro Canada Wash Oil (Water Soluable Fraction)

After aging the sample of Petro Canada Wash Oil in dilution water for 24 hours 50 per cent mortality was observed in the trout at the nominal concentration of 10,000 ppm. The aged sample (24 hour) was also toxic to *Daphnia*, where 12.5 per cent mortality was observed at 10,000 ppm.

Aging another sample for 96 hours proved to be more toxic to both trout and *Daphnia*. A single concentration trout test of 10,000 ppm showed mortality as 100 per cent. A full series trout test was set and mortality of 30 per cent was observed at 10,000 ppm, however an EC50 value of 8,062.2 ppm was estimated. The *Daphnia* test produced an estimated LC50

of 6474.2 ppm.

Dark Journal Oil (Water Soluable Fraction)

Dark Journal Oil was non-lethal to both trout and *Daphnia* at 10,000 ppm after aging for 24 hours. Aging the sample for 96 hours did have some effect on both species. Both trout and *Daphnia* exhibited 20 per cent mortality at 10,000 ppm.

Breslube (Water Soluable Fraction)

The sample aged for 24 hours was non-lethal to trout, however 25 per cent mortality did occur at 10,000 ppm in the *Daphnia* test.

Aging a sample of Breslube for 96 hours proved to be lethal to trout (30 per cent mortality observed at 10,000 ppm) and non-lethal to *Daphnia* at the same concentration.

Domtar Road Binder (Whole Product)

Daphnia were approximately four times more sensitive to Domtar Road Binder than trout. The estimated LC50 values for fish and *Daphnia* were 4336.6 ppm and 1341.6 ppm, respectively.

Dust Bond (Whole Product)

The LC50 values of Dust Bond for trout and *Daphnia* were estimated to be 535.0 ppm and 62.5 ppm respectively. Comparison of the LC50 values for trout and *Daphnia* suggest that *Daphnia* and approximately nine times more sensitive to Dust Bond than trout.

DCS-2

Comparison of the toxicity of DCS-2 to trout and *Daphnia* suggests that trout and the more sensitive species to the test material. LC50 values were estimated to be 191.0 ppm for trout and 521.1 ppm for *Daphnia*.

Tembind

Tembind has been determined to be more toxic to trout than to *Daphnia*. The respective LC50 values are 657.0 ppm and 3535.5 ppm. An EC50 value of 643.7 ppm was estimated for trout.

Calcium Chloride

Calcium Chloride was tested twice for both trout and *Daphnia* as there was inadequate volume of sample to allow for duplicate testing. Comparison of trout and *Daphnia* LC50 values suggests that Calcium Chloride was more toxic to *Daphnia* than trout. The LC50 values for trout and *Daphnia* were estimated to be 14,856.5 ppm and 6,386.6 ppm respectively. An EC50 was obtained for trout and was estimated to be 14,052.4 ppm.

The toxicity of the second sample of Calcium Chloride was comparable to that of the first sample. The LC50 values for trout and *Daphnia* were 19,413.2 ppm and 6301.0 ppm respectively. The EC50 value for trout was estimated as 17,668.5 ppm.

Oil Field Brine (Whole Product)

The initial LC50 value for trout was obtained by combining mortality data from the range test with the definitive test as there was insufficient sample volume to complete duplicate tests. The fish test was repeated on a second sample to confirm results of the first. the toxicity of first and second samples were comparable. LC50 values were estimated as 71553.9 ppm and 52304.8 ppm respectively. An EC50 value of 50360.3 ppm was estimated for trout in the second test.

The LC50 for *Daphnia* was estimated as 24,000.0 ppm. Comparison of LC50 values for fish and *Daphnia* indicate that Oil field Brine was approximately three times more toxic to *daphnia* than trout.

3.2 Comparative Toxicity of Dust Suppressants to Fish and *Daphnic*

Oil Field Brine exhibited the lowest overall toxicity to both fish and Daphnia. Comparison of their respective LC50s, suggests that the product was less toxic to fish (LC50 = 52,304.8 ppm) than to Daphnia (LC50 = 24,000 ppm). Relative toxicity of the remaining dust suppressant materials was assessed by relating toxicity of each product to that of Oil Field Brine (Tables 2a, 2b). Products were considered to exhibit lowest toxicity, if their respective LC50s for fish and Daphnia were within one order of magnitude of the corresponding LC50 for Oil Field Brine (i.e. 5,000 to 50,000 ppm for trout and 2,400 to 24,000 ppm for *Daphnia*); intermediate toxicity, if their LC50s differed by 1-2 orders of magnitude (e.g. 500 to 5,000 for trout); and highest toxicity, if their LC50s differed by more than 2 orders of magnitude (e.g. 50 to 500 ppm for trout).

Overall, acute toxicity to trout increased in the order of Oil Field Brine, Calcium Chloride, Bunker Fuel, Dark Journal Oil, Breslube, Petro Canada Wash Oil < Domtar Road Binder, Tembind, Dust Bond < DCS-2. Toxicity to *Daphnia* increased in the order of Oil Field Brine, Calcium Chloride, Bunker Fuel, Breslube, Dark Journal Oil, Petro Canada Wash Oil,

Tembind < Domtar Road Binder, DCS-2 < DCS-2.

4.0 Literature Cited

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APPENDIX A

DESCRIPTION OF LABORATORY DILUTION WATER

DESCRIPTION OF LABORATORY DILUTION WATER

Parameter	Dilution Water (mg/L)
pH (20 °C)	8.50
pH (20 °C) - treated	-
Conductivity (µmho)	252
TSS	< 1
Chromium (VI)	< 0.01
COD	13
TOC - Beckmann	10
DOC - Beckmann	10
Total Cyanide	0.001
Free Cyanide	0.001
Ammonia (as N)	0.032
TKN (as N)	< 0.2
Hardness (as CaCO3)	161
Fluoride	0.27
Chloride	0.76
Nitrite (as N)	< 0.04
Bromide	< 0.8
Nitrate (as N)	< 0.04
Phosphate (as P)	< 0.8
Sulfate	17
Alkalinity (as CaCO3)	150
Antimony	< 0.005
Arsenic	0.014
Mercury	< 0.0001
Selenium	< 0.005
Calcium	35
Magnesium	18
Sodium	4
Potassium	0.95
Aluminum	0.071
Barium	0.056
Beryllium	< 0.001
Boron	0.21
Cadmium	< 0.002
Chromium	< 0.004
Cobalt	< 0.01
Copper	< 0.006
Iron	0.073
Lead	< 0.02
Manganese	0.007
Molybdenum	< 0.02
Nickel	< 0.01
Phosphorous	< 0.06
Silicon	5.4
Silver	< 0.01
Strontium	0.094
Sulfur	7.4
Thallium	< 0.06
Titanium	< 0.01
Vanadium	< 0.005
Zinc	0.015
Zirconium	< 0.01

TABLES

Table 1. Summary of Acute Toxicity of Dust Suppressants to Rainbow Trout and *Daphnia magna*

Substance	BAR Sample No.	Sample Aged (h)	Date Tested (M/D/Y)	Test[A] Species	Effect	Value (ppm)	95% CI (ppm)	Method[B]	Slope
Petroleum Products									
Dust Bond	03910175	-	03/28/91	RBT	LC50	535.0	469.63 - 609.44	P	9.8
		-	03/27/91	Dm	LC50	62.5	55.24 - 70.71	P	8.2
Petro Canada Wash Oil	03910210	24	05/29/91	RBT	Lethal	50% mort.@ 10 000 ppm	-	-	-
		24	05/29/91	Dm	Lethal	12.5% mort.@ 10 000ppm	-	-	-
	03910330	96	06/01/91	RBT	Lethal	100% mort.@ 10 000ppm	-	-	-
		96	06/01/91	Dm	LC50	6474.2	5204.00 - 8054.46	P	6.5
	03910354	96	06/12/91	RBT	Lethal	30% mort. @ 10 000ppm	-	-	-
					EC50	8062.2	6500.00 -10000.00	GM	-
DCS-2	03910212	-	04/08/91	RBT	LC50	191.0	165.73 - 218.16	P	7.8
		-	04/09/91	Dm	LC50	521.1	415.07 - 726.60	P	3.5
Breslube	03910214	24	05/29/91	RBT	Non-lethal	@ 10 000 ppm	-	-	-
			05/29/91	Dm	Lethal	25% mort. @ 10 000 ppm	-	-	
	03910332	96	06/01/91	RBT	Lethal	30% mort @ 10 000 ppm	-	-	
			06/01/91	Dm	Non-lethal	@ 10 000 ppm		-	-
Dark Journal Oil	03910291	24	05/30/91	RBT	Non-lethal	@ 10 000 ppm	-	-	-
			05/30/91	Dm	Non-lethal	@ 10 000 ppm	-	-	-
	03910334	96	06/02/91	RBT	Lethal	20% mort. @ 10 000 ppm	-	-	
			06/02/91	Dm	Lethal	20% mort. @ 10 000 ppm	-	-	
Bunker Fuel	03910293	24	05/30/91	RBT	Non-lethal	@ 10 000 ppm	-	-	-
			05/30/91	Dm	Non-lethal	@ 10 000 ppm	-	-	-
	03910336	96	06/02/91	RBT	Non-lethal	@ 10 000 ppm	-	-	-
			06/02/91	Dm	Non-lethal	@ 10 000 ppm	-	-	-
Pulping Liquors									
Domtar Road Binder	03910172	-	03/27/91	RBT	LC50	4336.6	3876.91 - 4850.90	P	9.7
		-	03/25/91	Dm	LC50	1341.6	1000.00 - 1800.00	GM	-

Table 1. cont.

Substance	BAR Sample No.	Sample Aged (h)	Date Tested (M/D/Y)	Test[A] Species	Effect	Value (ppm)	95% CI (ppm)	Method[B]	Slope
Pulping Liquors									
Tembind	03910208	-	04/08/91	RBT	LC50	657.0	589.86 - 731.74	P	9.9
					EC50	643.7	578.28 - 716.50	P	9.8
		-	04/09/91	Dm	LC50	3535.5	2500.00 - 5000.00	GM	-
Calcium Chloride									
Calcium Chloride	03910173	-	03/27/91	RBT	LC50	14856.5	12440.02-17742.49	P	7.4
					EC50	14052.4	11465.05-17223.70	P	6.1
		-	03/25/91	Dm	LC50	6386.6	5272.67 - 7736.00	P	7.0
	03910261	-	05/06/91	RBT	LC50	19413.2	15739.64-24983.57	P	5.2
					EC50	17668.5	14107.12-22128.90	P	4.6
		-	05/04/91	Dm	LC50	6301.0	5192.02 - 7646.75	P	6.4
Brines									
Oil Field Brine	03910174	-	03/27/91	RBT	LC50 *	71553.9	57268.67-89402.48	P	4.0
	03910393	-	07/05/91	RBT	LC50	52304.8	44099.11-62037.24	P	5.2
					EC50	50360.3	43763.87-59398.17	P	6.3
	03910174	-	03/26/91	Dm	LC50	24000.0	18000.00-32000.00	GM	-

[A] Test Species
RBT = rainbow trout
Dm = Daphnia magna

[B] Method used to calculate LC50
P = Probit
GM = Geometric Mean

* mortality in 100 000ppm from range test included in calculations

Table 2. Comparative Toxicity of Dust Suppressants.

Toxicity of dust suppressants to rainbow trout.			
Relative Toxicity LC50 Range (Units)	Lowest 5,000 - 50,000 (ppm)	Intermediate 500 - 5,000 (ppm)	Highest 50 - 500 (ppm)
Dust Suppressants	Oil Field Brine[1]	Tembind	DCS-2
	Calcium Chloride	Domtar Road Binder	
	Bunker Fuel	Dust Bond	
	Dark Journal Oil		
	Breslube		
	Petro Canada Wash Oil		

Toxicity of dust suppressants to *Daphnia magna*.			
Relative Toxicity LC50 Range (Units)	Lowest 2,400 - 24,000 (ppm)	Intermediate 240 - 2,400 (ppm)	Highest 24 - 240 (ppm)
Dust Suppressants	Oil Field Brine[1]	Domtar Road Binder	Dust Bond
	Calcium Chloride	DCS-2	
	Tembind		
	Bunker Fuel		
	Dark Journal Oil		
	Breslube		
	Petro Canada Wash Oil		

[1] Toxicity of the individual products were related to the toxicity of Oil Field Brine (the least toxic material). Lowest, Intermediate and Highest categories were chosen on an arbitrary basis.